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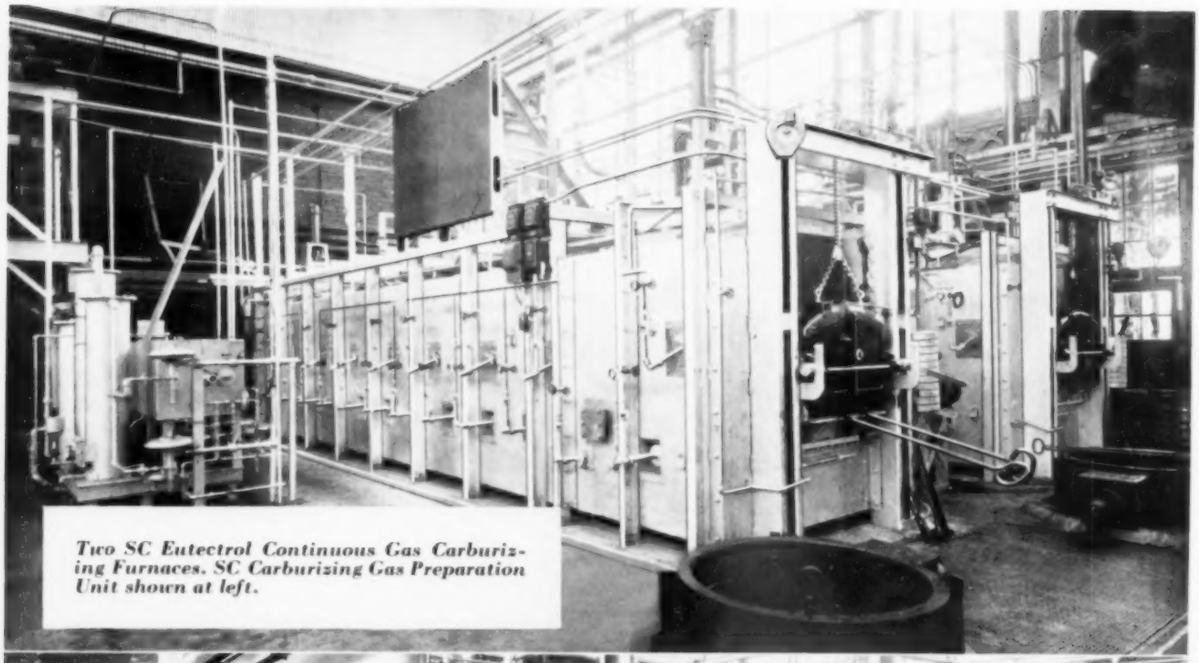
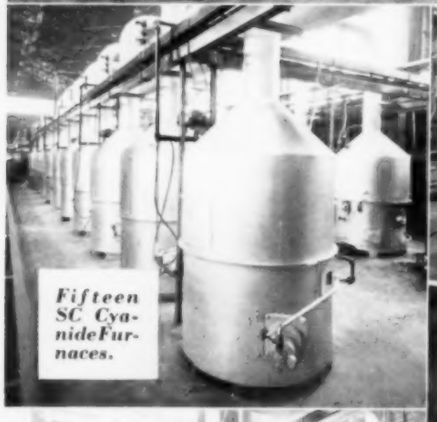
METAL PROGRESS

JANUARY 1936

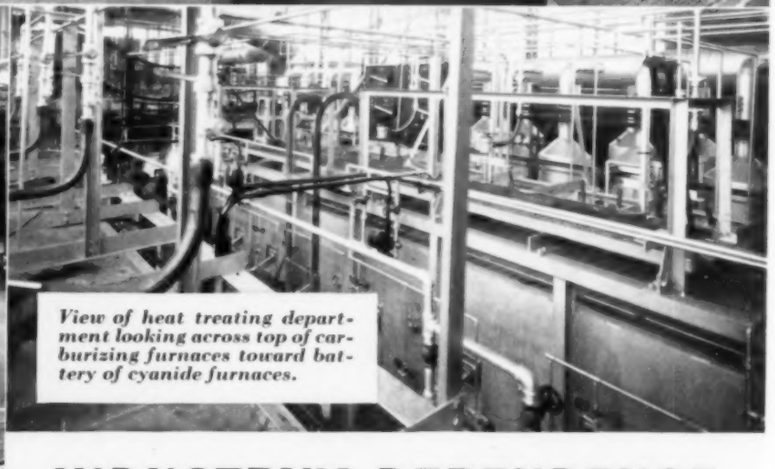
"THE RIVER MILL", PAINTING BY ROY HILTON, COURTESY PENNSYLVANIA STATE COLLEGE



Two SC Eutectrol Continuous Gas Carburizing Furnaces. SC Carburizing Gas Preparation Unit shown at left.



Fifteen SC CyanideFurnaces.



View of heat treating department looking across top of carburizing furnaces toward battery of cyanide furnaces.

Five-Station Lead Hardening Furnace.

INDUSTRY'S DEPENDENCE

In the Heat Treating Department of a large-scale production industry there must be utmost dependability. Inspection of heat treated parts is exacting, tolerances are held to close limits, rejects are ruinous. Continuous and economical operation with a minimum of maintenance is vital.

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METAL PROGRESS

January, 1936, Vol. 29, No. 1

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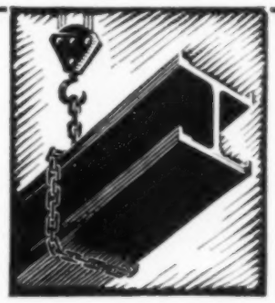

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Some Factors Affecting the

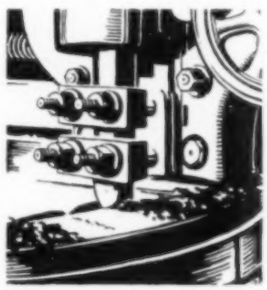
MACHINABILITY

of Steels and Other Alloys

NUMEROUS aspects of machinability were considered in a "round table" held recently by the Cleveland Chapter. The discussion spread out from the initial question: "Why should one shipment of S.A.E. 1020 bar stock cause so much trouble in the machine shop, while the next one be fairly easy to cut on a production basis?"

Such variations in soft steel, in the opinion of J. D. Armour of Union Drawn Steel Co., might be traced to difference in actual chemistry between the two shipments, or to difference in as-rolled grain size. An analysis (particularly carbon and manganese) on the low side of the S.A.E. 1020 specification would not machine as well as the high side. A fine grained, as-rolled structure would not machine as well as a coarse grained one. If a combination of low chemistry with fine grain happened to be obtained, it might show decidedly poorer machining properties than one on the high side of chemistry with coarse grained, as-rolled structure.

However, the rolling mill (hot mill) cannot be depended on to be a heat treating plant, as pointed out emphatically by William Leffler of Republic Steel Corp. Hot rolled bars cannot be expected to have that degree of uniformity of properties that is regularly induced in heat treated and in cold drawn bars. Gross irregularities can and should be avoided, but in his opinion the mill's responsibility is in furnishing material as uniform as possible, shipment to shipment and bar to bar, and then the machine and tool set-ups, when properly adjusted, would perform properly — or at least consistently.



There are so many factors involved in a commercial solution of the problem of machinability that no two shops will get the same answer. He cited one instance where one steel mill was shipping bars of the same size and analysis to three different manufacturers for one part of one automobile, yet the annealing, machinery, cutting tools, coolants and psychology were enough different that satisfactory results were had in three quite separate ways. Likewise, metal which gives *best* results in milling may not be in best condition for drilling, broaching or turning.

For these reasons it is impossible to dogmatize or to set a standard which will be best in all places. But a proper control of microstructure *and* hardness will generally enable a well-managed machine shop to avoid severe trouble. Mr. Leffler would classify the steels (exclusive of screw stock) into four rough groups in this respect, depending on carbon content:

The low carbon carburizing steels will generally machine best after normalizing, and the micro-grain of the normalized bar (depending as it does on hot working and cooling conditions), is naturally of more importance than the McQuaid-Ehn grain size. At best these steels are difficult to machine because the ferrite is continuous — a soft and ductile material, "sticky" and "gummy" to cut. In the higher carbon group, say 0.30 to 0.40%, stock should be normalized high enough to coarsen the austenitic grain and then cooled fast enough to give a very fine pearlite (sorbite) and with the minimum of free ferrite. In steels containing 0.50 to 0.60% carbon an annealed structure with

lamellar pearlite is best, making sure that the pearlitic granules are not entirely surrounded with ferrite. Finally in the eutectoid steels, a spheroidizing anneal is required.

To sum up, excessive ferrite must be avoided in the lower carbon ranges, but ferrite is utilized in supersaturated steels, and full pearlite is good in the intermediate ranges (0.50 to 0.60% carbon). In every case a micro-constituent is developed for use as a "chip breaker."

In all these classes the hardness ranges and relative machinability will, of course, depend on the alloy content. In the higher alloys, cooling rates after preliminary heat treatment are of utmost importance to avoid small patches of hard martensite.

Some customers have multiple requirements that demand diametrically opposite characteristics in one piece of metal. H. B. Pulsifer, chairman of the Cleveland Chapter, said that in this case a decision must be made as to what property was of most importance in fabrication and service, and worry along with the other. Speaking from experience in the cold heading industry, he said that rod that has an excellent structure for cold heading (one that deforms easily without undue work hardening) is one that is bad for machining, for the cutting tool pushing into the metal must deform a sliver of it and this should embrittle rapidly enough so it breaks off readily from the remaining stock. A compromise may sometimes be reached between cold heading properties and machining properties, if conditions are such that a little toughness in the cold-worked region can be sacrificed for improved cutting at the threaded end.

Of course, cold work will markedly improve machinability of many metals and alloys. Even though machinability is an exceedingly complex property of metal, Mr. Armour ventured the opinion that it depends on two main factors — low ductility and low strength. Low ductility (or stated better, a proper degree of dynamic brittleness) prevents the chip from clinging to the stock or balling up on the cutting tool.

Low tensile strength — in turn — means low power required to thrust the cutting edge under the chip and consequently less heat developed there; this also means longer tool life and less trouble with coolants. Now, whereas a soft steel bar will be strengthened considerably by cold drawing, the concurrent reduction in ductility is greater in degree, so the net result is an improvement in machinability.

Mr. Leffler's statement that microstructure is of prime importance to machinability extends also to screw stock and steels containing much free ferrite. Among others, J. V. Emmons of Cleveland Twist Drill Co. long ago showed that ferrite, while soft and easily cut with little wear on the tool, yet is also tough and easily deformed so it tears away from the stock, leaving a rough surface, and adheres to the cutting edge creating excessive frictional heat and drawing the temper of the tool. Mr. Armour cited the conventional means of retaining the good qualities of ferrite and eliminating the bad machinability by introducing manganese sulphide — a solid non-metallic inclusion — into screw stock. Spheroidized cementite particles in annealed steels of eutectoid analysis also act in the same way.

Brasses and Aluminums

This led H. P. Croft of Chase Brass and Copper Co. to inquire whether it did not constitute at least one general principle applicable to this complex subject that "A discontinuous structure makes for good machinability." A well-known illustration is gray cast iron, where a matrix which is really a high carbon alloy steel is made easily machinable by graphite flakes interspersed throughout. In his own industry a good example is the free-cutting brasses — they are essentially alpha solid solutions of copper and zinc in which a correct amount of insoluble constituent is dispersed. For ease and economy this constituent is lead. Another way to state the principle is: "A single phase matrix is improved in machinability by an insoluble constituent."

There is one curious fact about lead, however; its effect is much more pronounced in the high brasses than in the low ones. For example, 1.5% lead will do the same work in a 98% copper-zinc as 4.0% lead in a 63% copper-zinc alloy. Is this a general condition in other solid solution alloys?

While much stress has been laid on coarse grained steel for machinability (H. W. McQuaid having stated that 20 years ago at Timken Roller Bearing Co. the hours per grind on tools were increased from 6 to 24 by merely increasing the temperature at the last pass in the rolling mill), Mr. Croft doubted that this was a general principle. Some careful work on a high grade 70:30 brass (free from lead) showed that coarse grain has relatively slight effect, and what effect there is is in the opposite direction. For instance, when very fine grained (0.010 mm. average size), the machinability was 45% of standard free-

cutting stock, whereas after coarsening to 0.100-mm. grains the machinability was 43%.

Likewise he doubted whether it was safe to generalize about the influence of cold drawing. Annealed brass will drill better than cold drawn brass; the latter, however, will act better in a lathe, perhaps because it is then stiff enough so it will not bend away from the tool and cause chatter.

Aluminum and aluminum alloys generally are quite machinable as regards the power necessary to remove a unit volume of metal, observed L. W. Kempf of Aluminum Co. of America. To those familiar with the machining of copper and iron alloys, no difficulty will generally be encountered except perhaps in regard to finish. This is relatively easily remedied by making the cutting edge of the tools much sharper in all machining operations than when machining steels or brass. On lathe tools for example, the front clearance should be about 6° and the top rake angle very steep, making the included angle at the cutting edge 35 to 55°. The cutting edge should be smoothly finished.

While commercially pure aluminum is not easily machinable, the alloys are better fitted for these operations. The casting compositions which ordinarily have relatively high concentrations of alloy and therefore a discontinuous structure are usually more easily machinable than the wrought alloys. The latter usually have a relatively homogeneous structure because of the low concentration of alloy, as in the so-called common alloys, or because the material has been rendered homogeneous by heat treatment, as in the case of the strong alloys. There are, of course, many exceptions to the above generalizations. The silicon alloys, for example, are not as machinable as the copper (or copper and zinc) casting alloys because of the abrasive character of the silicon as compared with the copper constituent. Also, in the wrought alloys there has been recently developed a true free cutting stock. This material undoubtedly owes its excellent machining characteristics to the heterogeneous structure achieved by the addition of such insoluble elements as lead.

Reverting to former statements about deficient machinability of soft constituents like ferrite, he felt that the situation was not as simple as it would appear. Nothing so far said explained the remarkable ease with which commercially pure magnesium and its alloys could be cut. It had been suggested that the space lattice of magnesium was responsible, it being hexagonal whereas most of the other common metals are cubic. If this were the real reason it should also apply to zinc, which is also hexagonal, yet not particularly easily machined, especially when moderately alloyed as in die castings.

Difficulties in machining the single-phase austenitic steels used for gas engine valves were briefly mentioned by H. D. Bubb, Jr. of Thompson Products.

"Machinability" Means Different Things to Different Shops. Contrast the Boring mill on page 30 with this multiple head machine devised for several operations on an aluminum piston for a single handling. Courtesy Buick Motor Car Company

Turning operations are generally somewhat easier than drilling; in drilling it is necessary to *keep cutting* — if the edge momentarily fails to lift a chip and starts sliding it will not bite in again. In line with Mr. Croft's query noted above, Mr. Bubb was quite sure that the austenitic alloys are not nearly as machinable as those tending toward the martensitic structure. For instance, 18% chromium, 8% nickel machines much more readily than 14% nickel, 14% chromium. If 1, 2, or 3% silicon is added to the latter to improve scale resistance, difficulties increase.

Tool steels and tool alloys were also discussed briefly by others in the group at Cleveland. It was recalled that a very desirable aluminum piston alloy was held out of production a couple of years before the tungsten carbide tools were ready, so it could be smooth machined at a satisfactorily rapid rate. It is also well known that high speed steel of the standard 18-4-1 analysis has been modified by an increase of perhaps 0.10% carbon and a full per cent of vanadium, giving a modification which hardens 1 to 1½ points harder, and on tough, abrasive steels gives better life and much better finish.

A still further increase of the carbon and vanadium to about 1.25% and 4.5% respectively gives a very abrasion-resistant tool, intermediate between standard high speed steel and tungsten carbide. It is so full of hard carbides that it requires special grinding wheels for dressing, and is competing with the more expensive high cobalt tools for cutting hard and tough materials. The "moly high speed" invented by Mr. Emmons and described in METAL PROGRESS last June is also an economical substitute for high tungsten steels, and one finds several varieties of tool materials working side by side in the same production line, each on the operation where it is best fitted.

Others noted that tool problems in the smaller shops are solved with relatively few tools. If trouble is encountered recourse is frequent to a practice which would cause Taylor and White acute agony — namely, welding a hard alloy on a carbon steel shank. "Stellite" (cobalt-chromium-tungsten alloy) and "Toolweld" (molybdenum-tungsten high speed steel) are versatile and serviceable in this respect.

This Month's Cover

IS A REPRODUCTION from Penn State College's gallery of 50 paintings, adorning the walls of the School of Mineral Industry. Dean Edward Steidle has fathered the collection.

Welding With Covered Electrodes

By J. F. Lincoln

Condensed from Journal, Iron & Steel Institute

ARC WELDING with bare electrodes is carried on in the atmosphere, the liquid metal is superheated, forming relatively small-sized globules, the air is ionised, and the metal is in a thin layer in the crater. The time is relatively short, but the exposure is relatively great; manganese, carbon, silicon, and sometimes sulphur are removed and the iron is greatly oxidized. The metal cools rapidly enough to solidify before the oxides have time to rise. Some of the gas, such as carbon monoxide, may also be mechanically entrapped, with resulting porosity.

Therefore this weld metal contains oxides, slag inclusions, porosity, nitride needles; such metal is unsatisfactory.

An attempt should consequently be made to improve the quality of the weld metal by excluding the atmosphere. Metallurgists soon came to the conclusion that here was an opportunity to use alloys having an affinity for oxygen, so a number of them were tried. The result, however, was not as encouraging as was hoped. The tensile strength was increased, but the effect on the ductility was not particularly marked.

The other scheme is that of excluding the air. One of the earliest methods was to wrap the electrode with some refractory coating, such as asbestos yarn. This coating melts more slowly than the wire inside and thus forms a protecting sheath at the end of the electrode. This sheath offers some protection from the air, and also forms a slag covering on the bead of metal. This scheme has been in use for some time, and while there is a slight increase in ductility of the weld, there are other disadvantages.

However, the modern coated electrode has a coating which is either cellulose or mineral, varying from $\frac{1}{32}$ in. to $\frac{1}{16}$ in. thick, with a suitable binder. This covering forms a crucible, and has a further action: It supplies a reducing atmosphere through which the arc and small globules of metal pass; the crater is also covered by the reducing atmosphere, thus keeping the very hot particles of metal away from the highly ionised and reactive air.

The arc-stream and the crater are probably protected by the gases from the cellulose; for a mineral type of coating it is probable that each metal drop is enveloped by what might be termed a protective molten flux *(Continued on page 80)*

Electric Furnaces to

BRIGHT ANNEAL

High Carbon Stock

BY "BRIGHT ANNEALING" high carbon steels is meant annealing without oxidation and without decarburization. If, for instance, the steel is razor steel strip which, after hot rolling, is reduced to finished size in a series of cold mill passes, then the interspersed process anneals can be made by "bright annealing" without impairing the high surface polish acquired by cold rolling and without materially altering the carbon content at the surface. Or if the steel is hot rolled razor strip, drill rod or spring stock, "bright annealing" means spheroidizing the pearlite without decarburization — in fact, it may be possible to replace some of the carbon which has been lost at the surface during hot rolling.

To do this type of annealing the electric furnace is ideal, because close temperature control permits a lower annealing temperature, with resulting fineness and uniformity of grain — both features of such importance to this class of steels.

There are now a number of such bright annealing equipments in commercial operation, each combining with the electric furnace some devices for generating a protective atmosphere which is at once non-oxidizing and non-decarburizing. In addition to producing a superior product, these installations have shown remarkable savings in costs per ton of through-put, as compared to the older method of annealing with cast iron borings in pots or under a heavy cover. In the case of a razor steel, for instance, the saving amounts to from $40 to $50 per ton. There is another instance where grinding costs (for the removal of decarburized areas) have been reduced $35 per ton.

By Willard Roth
Power Engineering Dept.
Westinghouse Electric
and Manufacturing Co.

The reasons for these savings lie in the advantages inherent to the protective atmosphere, and in the sensitive, accurate temperature control of the electric furnace. Some main factors are as follows:

1. Elimination of borings or cast iron chips. This saves not only the cost of the borings themselves, but also the tremendous amount of heat absorbed by the borings and pots. By the same token, it is possible to greatly reduce the length of annealing cycle and so increase the productive capacity per annealing unit. Likewise the abrasive dust which adheres to stock when packed in borings is eliminated. Consequently there is less wear on cold mill rolls and drawing dies in subsequent operations.

2. Surface protection. The protective atmosphere envelopes every surface of the stock completely, and there is no local decarburization such as is apt to occur in borings due to air leakage, moisture or non-uniformity of the packing material. This means less grinding to remove decarburized areas.

3. Temperature control. The uniform anneal in the electric furnace has considerably reduced the number of process anneals for a given amount of cold working. For instance, in processing razor steel they have been cut in half. This is a major saving.

Economy of operation is one factor in the success of these installations; the quality of the product is another. The following brief description of a typical equipment,

its operating technique, and the resulting physical properties of the steels will be of interest to the metallurgist and engineer.

One of the first installations of electric furnaces in this service was made late in 1933. It was designed for bright annealing cold rolled and hot rolled, high carbon alloy and tool steels, in coils of flat strip and rounds. The halftone shows the installation, a battery of two bell type furnaces and four bases. There is also an ammonia dissociator and dryers.

Cylindrical bell furnaces are, of course, familiar to most of us, as they have found extensive use in the annealing of cold rolled strip-sheet and deep drawing stock. The bell type is the nearest approach to a continuous unit yet developed for heat treatments involving soaking and slow cooling. The bell is moved from base to base, in continuous cyclical operation, and thus the major portion of its stored heat is retained. Metal hoods, made of light-gage sheets of heat resisting alloy are sealed in oil at the outer periphery of the bases and protect the hot charge from oxidation. Due to the need for maintaining a dry atmosphere in this installation, the refractories on the base were also sheathed with alloy sheet, sealed in the oil trough, to prevent air infiltration.

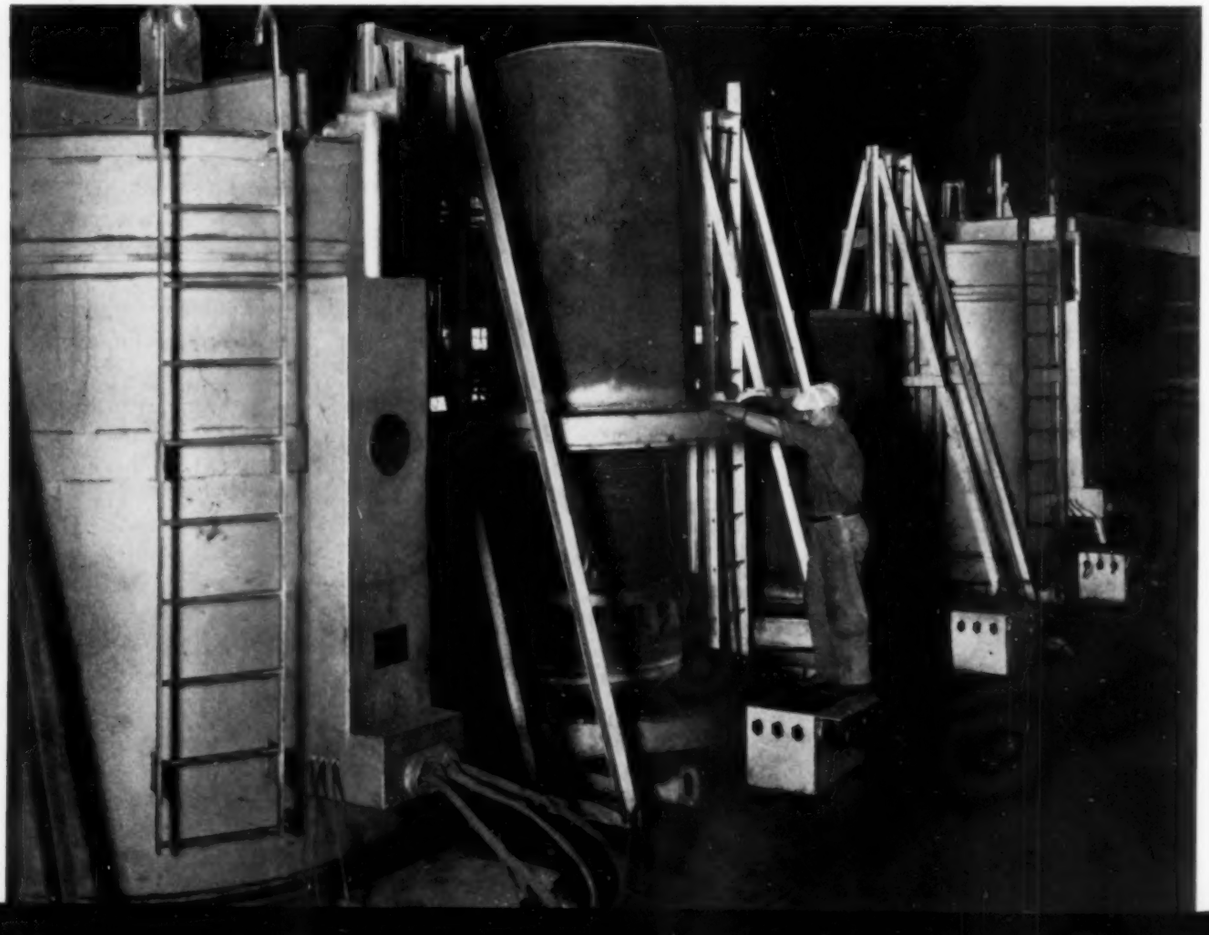
The furnaces are equipped with center heating elements, so that the stacked coils are heated from within and without. Charging space is 53 in. high and 38 in. outside diameter. A 16-in. core is reserved for central heating elements.

Dissociated ammonia was chosen for the atmosphere because preliminary research had shown that hydrogen or nitrogen, or a mixture of the two, has no appreciable decarburizing action in the absence of moisture. Anhydrous ammonia is an economical source of these gases in small quantities, and is easily kept dry after dissociation. (See METAL PROGRESS, April, 1932.)

As a matter of interest, later research has shown that gases resulting from the partial combustion of hydrocarbon fuel gases are also suitable when dried and properly purified. In addition, these gases can be made to have a mild carburizing action, tending to replace surface carbon lost in the hot mill.

In operating the equipment specified above, a base is loaded with stacked coils. Then a hood is placed over it as shown in the halftone, and sealed with oil on the outer, lower edge. The air is then flushed out, and the hot furnace bell is transferred to it from another base, where an anneal has just been completed. During the heating cycle, enough dry, dissociated ammonia

Battery of Electric Furnaces for Annealing Coiled Razor Steel and Drill Rod. Workman is lowering protective hood over stacked charge, and air is replaced by protective atmosphere. Hot cover, of bell type, is then moved from another base and the charge heated and cooled at definite rates



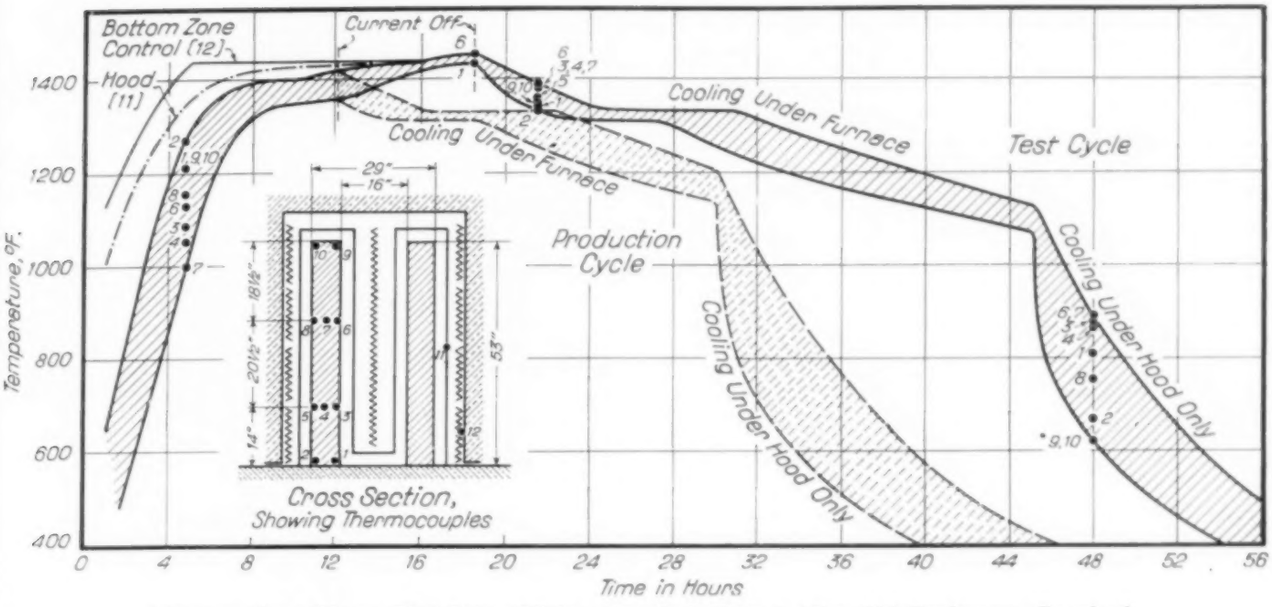
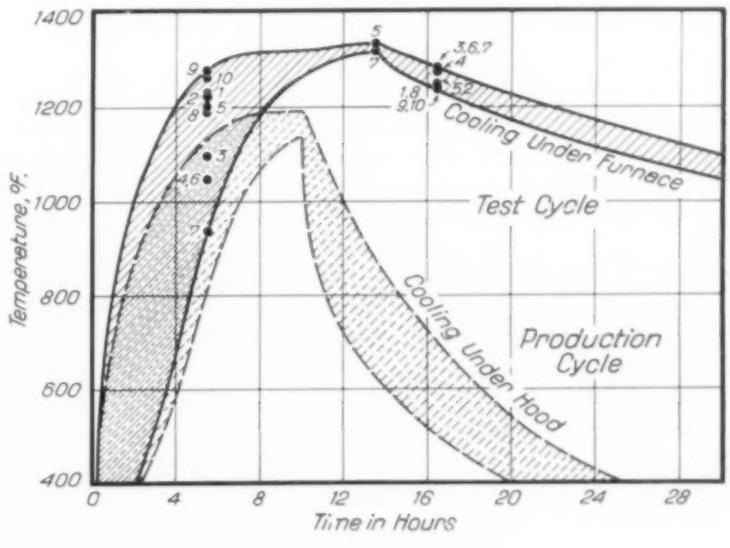


Diagram Above Shows That Spheroidizing Anneal, Patterned After Old Equipment, Required About 60 Hr., But the Actual Production Cycle in Electric Furnace Cuts This Time to 48 Hr.

is kept flowing through the charge to carry away oil vapors and moisture given off by the coils of steel, and thus keep the annealing atmosphere clean and dry. During most of the cooling cycle, circulation is stopped, and merely a slight positive pressure maintained, there being practically no consumption except that due to contraction of gas during cooling.

Such a cycle is shown graphically in the top diagram. It illustrates the characteristics of the equipment. Two cycles are shown; the long one is a test cycle made at the outset to determine the ultimate possibilities of the equipment; the other is a typical production cycle evolved later.

Below Is Log of Process Anneal in Electric Furnace; it Shows Saving in Time and Heat Over Old Plan of Annealing in Cast Iron Chips



There is a significant contrast between these two. The test heat was carried to 1435° F., a temperature substantially above the critical; at that time temperature variation throughout the charge was ±10° F. It was then cooled in the furnace (power off) to 1100° F., and thence down under protective hood only. This cycle was based largely on the previous practice of hot annealing under borings. It was soon discovered that this cycle was considerably longer than necessary in the new furnaces and after a period of trial and error the shorter production cycle was evolved.

In it the steel is heated barely through the critical range and then is cooled in the furnace to 1200° F. It will be noted that the temperature lag in the stack of metal at the end of the heating period with the short production cycle is about 50° F. This might be interpreted to mean that an annealing equipment which would produce an ultimate temperature variation of ±30°

F. would be satisfactory for this work. Such is not the case however. It is only because of the fact that the ultimate temperature distribution was ±10° F., as indicated by the best cycle, that we could be sure the variation would not materially exceed the natural lag as the steel *emerged* from the critical range. This natural lag, from outer and inner surfaces to middle of stack, is, of course, reversed during cooling and so tends to be compensated on the way. In other words, satisfactory temperature uniformity at the critical on cooling was the thing which enabled us to shorten the cycle and lower the top annealing temperature.

The test heat plotted on this large diagram carried a charge of alloy steel analyzing 1.20% carbon and 0.40% chromium. It was carefully studied and the following table shows the results at positions in the charge corresponding to the thermocouples of respective numbers shown on the curve sheet. Carbon analyses were made from millings 0.010 in. deep.

Data on Spheroidizing Anneal

Position in Charge	Surface Hardness Rockwell B		Surface Carbon	
	Before Anneal	After Anneal	Before Anneal	After Anneal
1	108 to 109	89 to 90	1.16%	1.00%
2	108 to 109	89 to 90	1.12	1.13
3	108 to 109	88 to 89	1.10	1.14
4		88 to 90	1.16	1.19
5	109	88 to 90	1.15	1.12
6	109 to 110	88 to 90	1.15	1.22
8	107 to 108	88 to 90	1.10	1.09
9	108 to 109	88 to 90	1.22	1.19
10	107 to 108	88 to 90	0.96	1.06

The resulting microstructure showed that spheroidization is virtually complete. Subsequent process annealing may, therefore, be done at relatively low temperatures and short cycles. The small curve sheet on page 37 illustrates a typical process anneal. Here again an initial test cycle, based upon pot furnace practice, is shown together with the production cycle which was eventually evolved with the electric furnace. After 10 hr. the temperature is sufficiently uniform throughout the furnace, and the steel is sufficiently softened so the bell can be removed. A short, low anneal means that the grain size of the finished product is much finer than would have been produced by the pot annealing equipment formerly used.

The foregoing data apply to flat stock. The following table shows the surface conditions obtained with ¼-in. alloy drill stock. Before annealing the stock had been hot rolled and pickled. Chemical analyses were made of chips turned from the surface in successive 0.005-in. cuts; "Step 4" therefore represents average conditions 0.015 to 0.020 in. below the surface.

Carbon Near Surface of Drill Rod

Position in Charge	Rockwell B Hardness After Anneal	Surface Carbon							
		Before Annealing				After Annealing			
		Step No. 1	Step No. 2	Step No. 3	Step No. 4	Step No. 1	Step No. 2	Step No. 3	Step No. 4
A	90 to 91	0.97	1.14			0.93	1.02		
B	89 to 91	0.88	1.12	1.13	1.17	1.02	1.09	1.15	1.17
C	90 to 92	1.02	1.11			1.11	1.13		
D	88 to 90	1.01	1.16	1.17	1.20	1.06	1.11	1.16	1.17
E	92 to 94	0.90	1.13			0.97	1.06		
F	89 to 91	0.93	1.14	1.19	1.19	1.04	1.12	1.15	1.16

These data are taken from a series of exhaustive tests made upon this installation, and are typical. The temperature curves and the surface hardness readings are indicative of the uniformity of anneal; the surface carbon analyses show the absence of decarburization during annealing — in fact, there is more generally a slight pick-up in carbon.

Now a further word about costs: In annealing flat stock such as razor steel or roller chain link stock, gas consumption requires about 5 lb. of ammonia on the average per ton of steel. Electric energy measures from 210 kw-hr. for process annealing to 300 kw-hr. for spheroidizing annealing per ton. This includes electrical losses at ammonia dissociator and transformer. The over-all annealing costs, basing depreciation upon a 10-year useful life, and including labor and maintenance, are of the order of $7 per ton for process annealing, and $12 per ton for spheroidizing.

In annealing coiled round tool stock, the density of loading is much lower than flat stock, being roughly in ratio 1 to 4 or 5. Hence, annealing cost per ton is proportionately higher.

Aside from its specific application to the high carbon steel field, the foregoing is of interest as an illustration of the possibilities which lie in the refinement of heat treating processes both from the atmospheric standpoint and from the standpoint of temperature control. The advantages and economies are often-times difficult to evaluate in advance of an actual trial, but are none the less real.

Closure of Pores in Tinplate by Electrodeposition

by A. W. Hothersall and W. N. Bradshaw

Condensed from Journal of the Society of Chemical Industry

TIN COATING formed on steel by the process of hot-dipping, or passing the steel, suitably cleaned, through a bath of molten tin, has invariably been found to be discontinuous or porous. The degree of porosity is usually high when the tin coating is thin but even relatively thick coatings are slightly porous. Pores represent a liability either to corrosion of the exposed steel or (in conditions where tin is anodic to steel) to accelerated corrosion of tin due to the electrochemical couple with the exposed steel.

D. J. Macnaughtan, Director of International Tin Research and Development Council, has patented the corrective process of electrodeposition of a thin coating of tin. (The Council will make arrangements for its use free of charge on application of interested parties.)

Tests were made with four acid plating solutions, but no substantial reduction in porosity was noted. Several alkaline baths were then used and all except those having a high free alkali content gave a marked reduction in porosity on deposition of 1 lb. of tin per base box (11.2 grams per sq.m.) on 1.5-lb. tinplate.

In view of its superiority over other alkaline tin plating baths, sodium stannate solution was used in the further tests. The solution containing 60 to 80 grams Sn and 20 grams of free NaOH per liter was used with insoluble anodes under the following conditions: Temperature 70 to 75° C., current density 15 amp. per sq.ft. Under these conditions, the time required to deposit a thickness of tin equal to 0.25 lb. per base box was about 80 sec.

The superior behavior of alkaline over acid tin plating baths in sealing pores in hot-dipped coatings is probably due to a number of factors: (1) Alkaline tin baths have an exceptionally high throwing power, largely due to the marked decrease in current efficiency with increase in current density. Crevices in the tin coating, and also in the steel base, will thus be coated more readily. (2) The couple formed between the tin coating and steel exposed at a pore has a higher e.m.f. in the alkaline than in the acid plating baths (for example, 0.8 volt in the sodium stannate solution, 0.1 volt in the oxalate bath); the direction of the couple is the same in both baths, steel being the cathode. The potential thus given to the steel assists that applied from external sources and increases the rate of deposition on the microscopic exposures of steel. (3) The alkaline bath exerts a cleansing action which would assist in removing any grease from pores.

Prior to deposition the tinplate must, of course, be degreased. Comparisons were made of plan *(a)* swab with trichloro-ethylene, dry, and put dry into plating bath; and plan *(b)* boil 5 min. in 1% solution of waterglass, rinse, and put wet into bath. The latter seemed more effective.

Porosity was measured by the hot water test of Macnaughtan, Clarke and Prytherch, developed at Woolwich arsenal. This method consists of keeping the degreased tinplate in upright position in distilled water at 95° C. for 6 hr. Adherent rust spots form at pore sites, rendering them clearly visible. Porosity is measured by counting these spots in unit area. The water used must be of high purity, distilled, stored and heated in block tin or heavily tinned copper vessels. It should be neutral or very slightly acid. To determine this, add five drops methyl-red indicator to 10 c.c. of the water; the color should be pale pink without trace of yellow tint.

Average results from over 300 specimens showed that tinplate (1 lb. 8 oz. per base box quality) had about 1000 pores per sq.dm. After 0.25 lb. per base box of tin had been electrodeposited, porosity was reduced to 135 pores; 1.0 lb. reduced it to 44 pores; 4.0 lb. reduced it to 5 pores, and 8.0 lb. reduced it to nil. The average porosity of hot dipped coatings of equal total thickness is 10 to 20 times that of the composite coatings; furthermore pores in composite coatings appeared smaller than those in hot-dipped.

Composite coatings of this sort developed marked porosity when bent around small radius, either with or across the direction of rolling. However, electrodeposition *after* bending a hot dipped sheet had a marked effect; porosity was practically eliminated on all bends made at right angles to the direction of rolling by the electrodeposition of 1 lb. of tin per base box; 4 lb. of tin per base box (45 grams per sq.m.) was required to eliminate porosity at bends made parallel to the direction of rolling. The process thus appears likely to prove of value when applied to fabricated articles if porosity is to be avoided.

Methods of Hardening

CAST IRON

by Heat Treatment

AN ARTICLE in the last issue discussed the methods of securing hardened (yet usually machinable) irons by alloying. Cast iron can also be hardened by heat treatment by merely applying the fundamental principles of the hardening of steel, or, reduced to specific terms, castings are heated to 1450 to 1550° F., quenched in oil, and tempered somewhere in the range of 450 to 1000° F., depending on the toughness required. Almost every cast iron will respond to some extent to a treatment such as this because the cooling in oil is considerably more rapid than had occurred in the original mold and some hardening action can be expected of whatever carbon has not been graphitized.

As in the case of steel, the hardening power of an iron depends on the amount of dissolved carbon and other elements in it. Carbon is again a very important element. In cast iron it may be present in any amount from 2.0% to 4.0%, but most of this will be in the form of inert graphite flakes. It is the residual, ungraphitized carbon that exerts the most important effect.

An ordinary gray iron casting may contain anywhere from 0.10 to 0.90% of this dissolved or combined carbon and its response to heat treatment will vary correspondingly. The fully quenched hardness of a 0.10% carbon steel is about 250 Brinell and that of a 0.90 carbon steel is in excess of 500. Since the extreme ends of this carbon range might exist in a single casting made by conventional foundry methods, it is evident that something must be done to assure uniformity and reproducibility.

The problem of obtaining a balanced, full bodied type of iron was discussed in the previous article. It is not so difficult to achieve today as in the foundries of, say, 1930. The composition must allow the casting to possess, initially, a fine distribution of graphite, complete freedom from massive carbides or carbide clusters, a tendency to harden — evenly and deeply — as cast, and yet possess relatively free and easy machinability.

Illustrations of how typical cast irons respond to a quench and draw are given in the diagram on the opposite page. By comparing the curves marked No. 1 and No. 2 it will be seen that low silicon irons harden better, for they are initially finer grained and dense and less inclined to graphitize.

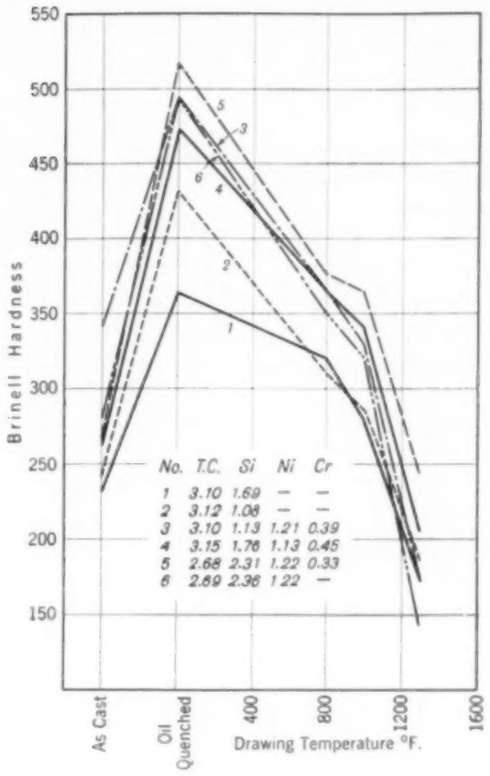
Other suitable base compositions are the high test types possessing a low content of total carbon (best around 2.80%). The silicon in these irons should also be low. It is in compositions like these that nickel, chromium and molybdenum come into action to make cast iron worth heat treating. Nickel is undoubtedly the most important — even more so than in a comparable steel — because it prepares a good foundation structure responsive to the heat treatment. By its strong and positive dislike for carbides, nickel breaks them down while the casting is in the semi-plastic state; at the same time, it resists the diffusion of carbon in the solid state, so that its presence effectively puts brakes on the rate of graphitization.

Such irons (low in silicon, kept close-grained, dense and free from excess carbide by appropriate additions of nickel, treated with chromium or molybdenum to increase the hardening depth if the sections are large)

by J. S. Vanick
International Nickel Co. . . . New York

contain their fill of combined carbon, and chromium and molybdenum are balanced so that they do not form free carbides. The microstructure, exclusive of the graphite, should therefore correspond to that of a 0.60 to 0.85 carbon steel. Whether it is pearlitic, sorbitic, or martensitic at this stage may be less important than whether it is clear of carbides or free ferrite.

Soft irons, high in silicon or carbon, will graphitize further during heating for quenching, drawing or annealing, even when the temperature is but mildly raised to encourage diffusion of carbon. The half tone below shows the additional fact that heavy sections fail to harden through, unless substantially alloyed. Heating temperature should be as low and the heating as short as necessary even in the alloyed irons low in carbon and silicon.



Low Silicon Irons, High Test Irons, and Properly Alloyed Irons Have Good Response to Oil Quenching and Drawing

Quenching

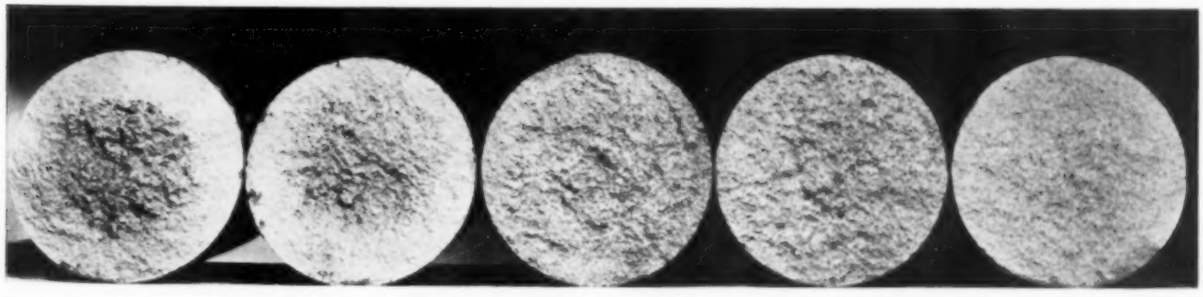
"Quenching from above the critical" usually means from above 1400° F., and rarely is a higher temperature than 1550° F. necessary or desirable. The high carbon content of the iron assures you of a low critical range; certain elements like nickel lower it further, but silicon, chromium, and others raise it. A correct quenching range is 1450 to 1550° F. where alloying elements (including silicon, nickel, chromium and molybdenum) add up to less than 5%.

Oil quenching is apparently best, because the high carbon content and tenderness of iron make it strongly susceptible to cracking if a violent cooling rate is applied. This is indicated in the low tensile properties of quenched irons, while the hardness promptly increases.

After quenching comes the usual tempering, preferably started while the castings are warm. They are reheated slowly to 400 to 1000° F., and allowed to cool slowly or with the furnace. In some cases, castings may be used as quenched — the high hardness being more important than the strength. A tempering temperature of 600 to 750° F. sacrifices very little hardness and achieves considerable toughness due to the relief of quenching stresses. For maximum strength and toughness along with a good hardness desired for most castings, the tempering temperature will reach 750 to 900° F.

Heat treated irons must be machined prior to treatment. In some cases a softening anneal may be safely applied to speed up machining

Fracture of 3-In. Cast Rounds, Oil Quenched From 1550° F. Surface hardness taken with 10-mm. tungsten carbide ball



Type	Plain	Plain Hi-test	Nickel Hi-test	Ni-Cr Die	Ni-Cr Die
T.C	3.37	2.79	2.77	3.44	3.37
Si	1.49	2.58	2.16	1.55	1.47
Ni	...	...	1.15	2.22	3.56
Cr	...	...	...	0.98	1.56
Hardness	387	321	475	444	512

rates. For instance, an iron possessing an initial as-cast hardness of 280 Brinell may be annealed to 180, machined, then quenched to 500 or more and tempered as desired.

These processes must be applied in the proper sequence, and attention paid to volume changes. Annealing may cause mild distortion, and further slight changes take place during quenching and tempering, but this can be taken out by final grinding if closest tolerances must be met.

An excellent example of these principles is the gas engine cylinder liners and sleeves shown in the accompanying striking photograph and described by P. E. Eddy before the American Foundrymen's Association in 1934. Composition of these casting is as follows:

Total carbon	3.10 to 3.40%
Combined carbon	0.75 to 0.90%
Manganese	0.55 to 0.75%
Phosphorus	0.20% max.
Sulphur	0.10% max.
Silicon	1.90 to 2.10%
Chromium	0.55 to 0.75%
Nickel	1.80 to 2.20%

Gas Engine Cylinder Sleeves, Alloy Iron, Machined, Hardened and Ground, Are Capable of 500,000 Miles Driving Before Regrinding Is Necessary

Properties of Heat Treated Cylinder Liner Castin

Condition	Tensile Strength	Hardness	
		Vickers Brinell	Rockw
As cast	37,000 to 41,000	217 to 248	B-96 to
Aged	38,000 to 43,000	217 to 248	B-96 to
Oil quenched from 1550°F.	28,000 to 36,000	570 to 650	C-52 to
Drawn 2 hr. at 300°F.	33,000 to 39,000	530 to 610	C-50 to
Drawn 2 hr. at 350°F.	36,000 to 40,000	500 to 580	C-48 to
Drawn 2 hr. at 450°F.	39,000 to 43,000	470 to 530	C-46 to
Drawn 2 hr. at 600°F.	45,000 to 56,000	450 to 500	C-44 to

When machined to about ⅛ in. wall thickness they must be leak proof against 1500 psi. hydraulic pressure. They are then heated 35 min. at 1550° F. and quenched in still oil. Physical properties are as shown in the table at the top of the page.

Eddy points out that the hardened cylinders are able to deliver two to three times the mileage between reconditionings that could be obtained from the old style cylinders 230 to 240 hard, and that the ultimate life of one hardened to over 500 Brinell is correspondingly increased. In mileage a lift from 75,000 miles for the 240 Brinell cylinder to 200,000 is achieved between reconditionings and a total mileage exceeding 500,000 miles can be expected for the cylinder 500 Brinell hard!

Other castings that are commonly heat treated to resist wear are dies, piston rings, valve plugs, textile and shoe machinery, as well as many other small, fast moving parts.

"Over-Alloying"

Means are available to avoid much of the distortion caused during the oil quenching treatment. Hurst, for instance, recommends using a larger amount of alloy than for oil quenching and substitutes an air quench. Lower hardnesses are developed by this practice (say 400 Brinell rather than 460).

Ballay and his associates hit upon the idea of loading a cast iron up with enough alloy so that it would be austenitic and soft as cast or quenched but after machining could be annealed into a hard condition (that is, converted into a martensitic structure). To a good grade of gray iron may be added 4 to 6% nickel, 1.0 to 1.5% chromium, some extra manganese, and possibly a little molybdenum — all balanced so that no free carbide forms — and an iron suitable for the Ballay treatment is obtained.

Delbart, employing a nickel-manganese com-

position achieves similar results. The following example is taken from his paper in *Transactions*, American Foundrymen's Association, 1935. Prior to annealing the Brinell hardness was 160, the tensile strength 28,720 psi., and the elongation 1.40%. After annealing 15 hr. at 1110° F. the hardness had increased to 418, the strength to 46,310 and the elongation dropped to 0.65%. Composition was, total C 2.65%, Si 1.80%, Ni 6.50%, Mn 3.75%, very low in phosphorus and silicon.

Thin castings, such as engine or motorcycle sleeves, can be cast of these compositions to an initial softness of about 250 Brinell. If an additional softness is desired, the castings are heated and quenched in oil or water. To some extent this encourages distortion. After rough machining the casting, it is given a hardening anneal or normalize at 1100 to 1300° F. and cooled in the furnace, in a sand pile, in the air, or a mild air blast. The anneal raises the hardness to about 380 Brinell; distortion is nearly absent so that in many cases final grinding may be omitted entirely.

In addition to water-jacketed cylinders, gears, cams, and other light castings, this procedure can undoubtedly be safely applied to heavy, complicated castings where quenching is out of the queston and distortion must be kept at a minimum.

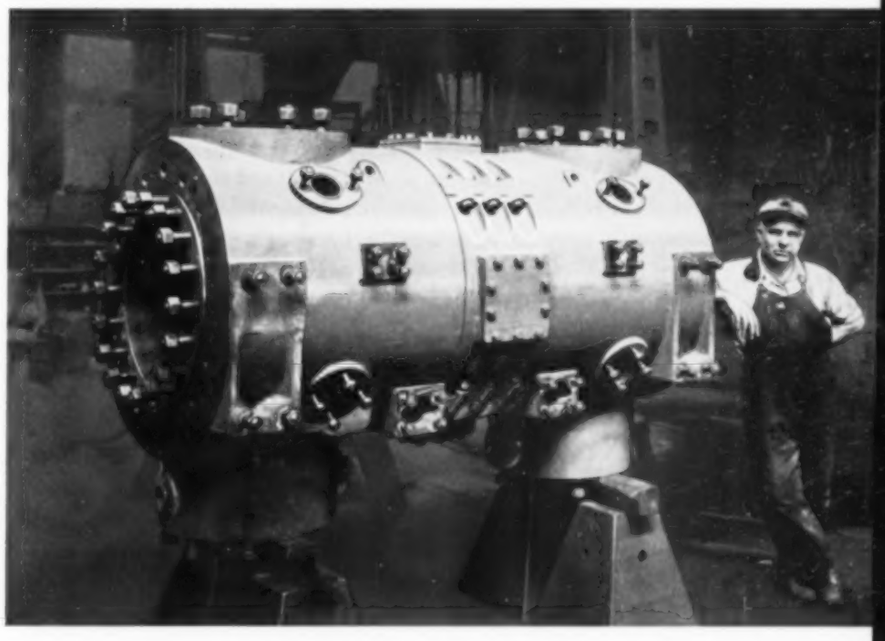
Surface Hardening

Nitriding — Published work on an alloy cast iron ("nitricastiron") by Messrs. Homerberg and Edlund indicates that a hard case 0.010 to 0.015 in. thick can be produced after 60 hr. at 950 to 1000° F. in ammonia. Composition quoted by these authors was: Total carbon 2.50 to 2.90%, silicon 1.50 to 1.60, manganese 0.60, aluminum 1.0 to 1.25%, chromium 0.20 to 0.40, and molybdenum 0.60 to 0.75%.

The growth in size is reported to be 50% greater than in steel ("nitraloy") of similar alloy content. The present writer believes that a tougher surface, lower dimensional change and good wear resistance can be had in a low silicon nickel-chromium cast iron, as shown in the lower figure on page 45 of last month's issue.

Cyaniding — Most cyanided cast iron is quenched from the bath, so some doubt exists as to whether the cyanide or the quench develops the hardness. At any rate, file-hard surfaces are obtainable if conditions are right. A good foundation is necessary to support the thin case, and a hardenable cast iron of the Ni-Cr or Ni-Cr-Mo type makes a good base. Castings treated this way are usually small and, due to the limitations of cyanide containers, handled in small quantities. Examples are knife edges for the bath room type weighing scales, as well as many small parts for sewing machines and other light types of machinery.

Pack hardening has a doubtful place in hardening cast iron, yet is practised to some extent, chiefly on machine tool parts. A soft cast iron, machined to finished dimensions, could only be packed in a carburizing mixture and heated at a high temperature for a long time. The tendency to graphitize what little carbon remains dissolved and the impedence which the usual high silicon content offers to inward migration of carbon is likely to make the result of doubtful value. Most of such parts could be better prepared for their service by employing a better balanced base composition and hardening the part by some of the simple and more reliable methods outlined above. An article by F. J. Dost in METAL PROGRESS last August will illustrate the method.



Heavy and Complicated Castings Quenched to Austenitic Microstructure and Machined, Then Hardened Without Distortion by Annealing to Martensite

High Chromium Alloys—

CENTRIFUGAL

Castings and Tubes

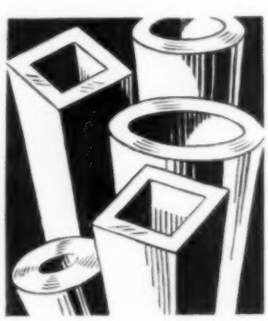
COMMERCIAL production of the highly alloyed centrifugally cast products by at least four American foundries represents a distinct contribution to those industries using the high chromium-nickel-iron alloys. This can be more fully appreciated when it is realized that rather definite limitations exist in the hot working of these alloys in the form of seamless tubing. Alloys exceeding the 18% chromium, 8% nickel composition are increasingly difficult to work, and only recently have wrought seamless products been commercially available in one or two compositions up to 25% chromium, 20% nickel. Likewise, the difficulties of casting light-walled tubing of sizable lengths and diameters by conventional sand casting methods are well familiar to any foundryman.

The centrifugal casting process is not new — it has been used successfully for several years both in this country and abroad in the manufacture of cast iron pipe. Carbon steels and mild alloy steels as well as non-ferrous materials are also being cast into cylindrical shapes by this method with satisfactory results. In many cases materials are produced having more satisfactory properties than sand cast tubular shapes and for some applications superior to forged products. (See Col. T. C. Dickson's paper in *Transactions*, A.S.S.T., Vol. 18, p. 212 on "Casting Guns by the Centrifugal Process.")

It is not surprising, therefore, that the centrifugal casting process has been adapted to the highly alloyed heat and corrosion resisting materials. In this respect the process may be regarded as a comparatively new development in the alloy casting industry, but it has made rapid strides as the knowledge of the mechanical and metallurgical aspects unfolds.

by R. J. Wilcox

Chief Metallurgist
Michigan Steel Casting Company . . . Detroit



Machinery used in the alloy foundry does not differ essentially in principle from that used in the production of centrifugally cast pipe of gray iron. The machine consists of a motor-driven rotor or rotating mechanism which engages and spins the cylindrical mold. The latter's axis is usually in a horizontal position. A suitable pouring spout is provided at one or both ends of the mold for introducing the liquid metal. The mold may be either of metal or refractory. In the former case the mold is "permanent" and with proper precautions may be used repeatedly, while with a refractory lining a new mold is required for each cast. Both types present advantages and disadvantages in operation, and a considerable literature exists on this point.

The process employed by the Michigan Steel Casting Co. makes use of a refractory lined mold. This has distinct operating advantages when producing an extensive number of tube sizes requiring either plain or flanged ends and sometimes with varying contour on the outside surface. Erosion of the mold wall does not present serious difficulties since most of the highly alloyed products are ordered in comparatively light wall, ranging from ⅛ in. upwards.

Process of Manufacture

The process is more difficult to execute in the highly alloyed ma-

terials than in cast iron or heavy-walled steel cylinders. The inherent sluggishness of high chromium-nickel-iron alloys in the liquid state and their rapid rate of solidification present problems which are not encountered in the handling of materials of lower melting point or greater fluidity. Operations must therefore be highly coordinated and timed and metal temperatures carefully controlled.

The first step in the production of a tube consists in the preparation of the mold. This is accomplished by securely ramming sand around a cylindrical metal pattern which is accurately centered in the flask so that the mold surface corresponding to the outside diameter of the casting will revolve concentrically about the axis of rotation of the casting machine. (It is apparent that a pattern is required for each outside diameter of tube to be produced.) The mold is then dried in a vertical position in an oven capable of maintaining uniform temperature throughout the length of the mold. After drying, the mold (still in its flask) is transferred to the machine, locked in place, and the pouring spout placed in position. The mold is then rotated at a predetermined speed depending upon diameter, thickness and length of the casting.

A Few of the Shapes Cast Centrifugally, Illustrating Some Modifications Possible in the Outside Contour

The required amount of metal to form the desired wall thickness is then accurately measured and introduced through the pouring spout, where it lines the spinning wall of the mold due to the centrifugal force developed and spreads uniformly the entire length of the opening. Spinning is continued until solidification, after which the flask, mold and casting are removed from the rotating mechanism. The casting is then sent through the usual cleaning processes, heat treated if required by the particular alloy composition and service, and finally tested by means of hydraulic pressure.

Concentricity of the tube wall depends on the accuracy of mold preparation and the balance (concentricity) of flask and rotating mechanism. Uniformity of longitudinal section is a function of the fluidity of the metal and the centrifugal force developed (which in turn depends on the speed of rotation, the diameter of the tube, and the wall thickness). The limiting ratio of wall thickness to tube length depends upon the particular type of alloy. The stainless types such as 18-8 and 29-9 are conveniently cast in 9-ft. lengths with a $\frac{5}{16}$-in. wall and diameters up to 12 in. The 35-15 type of heat resisting alloys is more fluid and can be conveniently run in longer lengths and with walls as light as $\frac{1}{8}$ in.

Metallurgy

All of the commonly used heat and corrosion resisting alloys are being produced in the form of centrifugal castings. This includes such materials as the 35% Ni, 15% Cr, and 65% Ni, 15% Cr heat resisting types and the 29% Cr, 9% Ni; 21% Cr, 12% Ni; 18% Cr, 8% Ni; 18% Cr, 8% Ni, 3% Mo alloys; the straight chromium alloys (16%, 18%, and 28% chromium-irons); as well as corrosion resisting cast iron high in nickel and chromium. The carbon content in our corrosion resisting alloys varies from 0.10% max. in the 18-8 type to 0.30% max. in the 29-9 alloy.

Due to the rapid action of centrifugal forces, the tube is formed very quickly after the liquid metal enters the mold. In the case of a 9-ft. tube having a $\frac{5}{16}$-in. wall and an inside diameter of 8 in., the uniform distribution of metal on the mold wall takes approximately 7 sec., and solidification is completed some 60 to 90 sec. later. Due to this relatively rapid rate of formation and solidification, the segregation of carbon and other elements noted by some investigators in heavy-walled steel tubes does not appear to present serious problems in the rather light-walled material produced to date. For instance, metal shaved from the inside and from the outside of

a 4-in. tube, $\frac{5}{16}$-in. wall, 29-9 alloy, analyzed as shown in the following table:

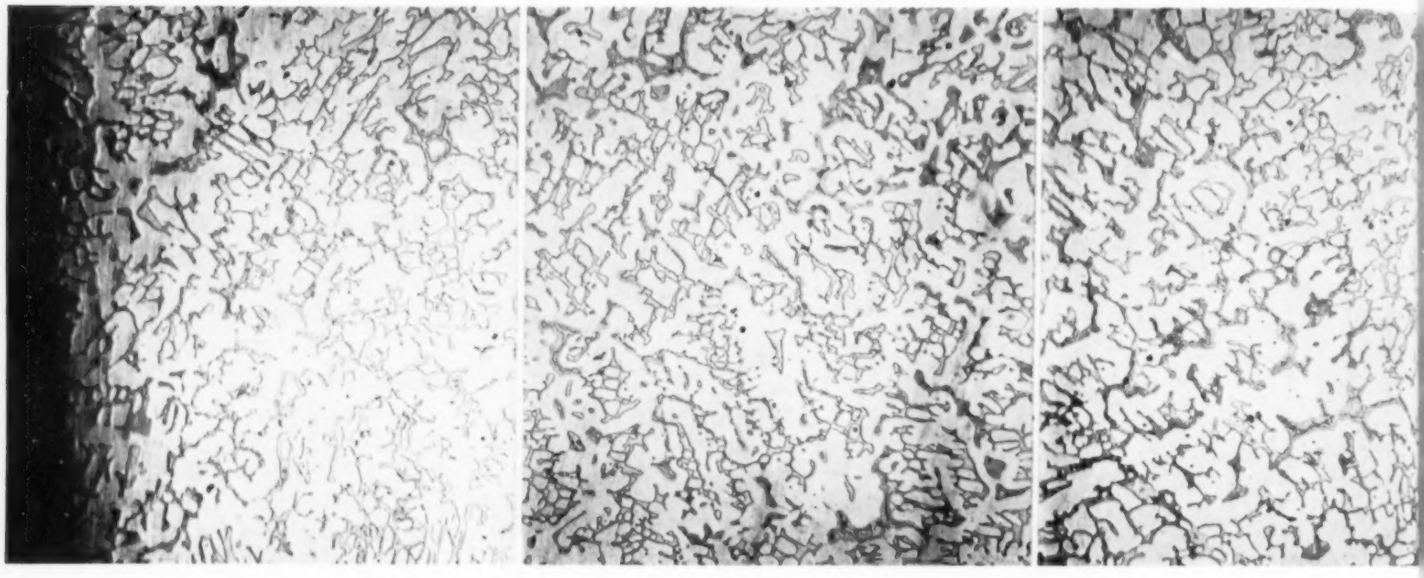
	C	Mn	Si	Ni	Cr
Inside	0.26	0.35	1.10	9.53	29.00
Outside	0.26	0.38	1.07	9.67	28.60

Microstructure of this tube is illustrated just below; the three views indicate the structure to be quite uniform from inside to outside.

Similar microsections of 35% Ni, 15% Cr alloy in the centrifugally cast condition were made on a tube having a ¼-in. wall. The heat analysis was C 0.73%, Mn 0.76, Si 1.20, Ni 36.30, Cr 16.61%. The characteristic dendrites of the sand cast material in the "as cast" condition are not completely absent in these light-walled tubes of high alloys (as has been claimed for centrifugal steel castings). This may be due to the fact that sufficient centrifugal force has not been brought into play over a long enough period, due to the rapidity of solidification. Certainly, dirt or foreign material is rejected toward the inside surface of the tube, and is indicated in the photomicrographs by an increasing number of small black specks. Thus it appears that centrifugal force, even in sections as light as ¼ in., has had its characteristic effects in the few seconds required for solidification.

A partially machined section of 29-9 alloy tube having an inside diameter of 6 in. and a $\frac{5}{16}$-in. wall is shown in the view on page 47 in order to illustrate the freedom of the outside surface from sand or slag inclusions. This tube was cast 9 ft. long. The machine cut was very light, approximately $\frac{1}{512}$ in., and no surface imperfections were visible to the naked eye. Despite the rapid solidification the grain size, as cast, suggested by the mottling on this machined surface is rather large.

Another section of the tube is shown, severely macro-etched in 1:1 HCl. The macro-etch indicates the absence of any serious annulated formations and the section appears fairly uniform. The crystal arrangement radiates from the outside surface toward the center. Despite these appearances of coarse crystallization the tube as cast is quite tough, as proven by a section cut from the same tube which was compressed to illustrate the ductility. An X-ray survey of this tube also indicates a satisfactory condition of soundness with the absence of any cracks or serious segregation.



Uniform Microstructure, Outside, Center, Inside (Respectively) on Section of 4-In. Tube of 29-9, Centrifugally Cast. 100 ×

Comparative physical tests on the various alloys in the centrifugally cast condition and the statically cast condition are not complete. However, it appears that the centrifugal product has approximately equal strength in the light-walled sections, and has equal or perhaps even better ductility.

Some tests made on the 35-15 alloy tube referred to above may be compared to a sand cast,

standard coupon 1⅛x1⅛x6½ in. In reviewing these results it should be borne in mind that the sand cast coupon had a sizable feeding head somewhat larger than the coupon itself in order to avoid pipe. Both samples were poured from the same heat (analysis given above) and were tested as cast. The centrifugally cast specimen was taken from a longitudinal section.

Properties of 35% Ni, 15% Cr

	Centrifugal Tube	Sand Cast Coupon
Yield point	45,670 psi.	52,500 psi.
Tensile strength	63,890 psi.	65,125 psi.
Elongation in 2 in.	2.0%	2.0%
Specific gravity	7.91	7.97

In general, the centrifugally cast products are finding applications wherever cylindrical shapes are required. These shapes may be modified on the outside surface to include ribs, lugs, flanges or slots, as long as provisions may be made in the mold for unrestricted contraction and uniform balance of the entire unit about the longitudinal axis. Thus it is impractical to cast tubes with flanges on both ends — the restriction offered contraction would be sufficient in long lengths to cause rupture of the casting. Flanges can be conveniently cast on one end of the tube. A few exam-

6-In. Tube of 29-9 With Outer Skin Machined Off Shows Clear Surface, Free From Defects and Capable of Taking a High Polish. Flattened ring illustrates toughness, as cast. Macro-etched ring shown below, full size, is free from any annulations parallel to surface

ples are photographed and shown in the half tone on page 45.

Examination of tubing which has required a brilliant surface polish indicates that a high order of surface perfection together with straightness and accuracy of size is within the scope of commercial production; it also indicates the feasibility of greatly reducing the generous allowances for machine finish ordinarily required on the conventional sand casting.

Application

Corrosion resisting alloys find extensive use in the form of chemical piping, rolls and rollers, cylinder liners and similar items. In the heat resisting materials, the process is readily adaptable to the manufacture of light-walled carburizing pots. Bottoms and covers are sand cast in proper design, the bottom being welded to the cylindrical shell. These containers are usually made with a modified flange on the open end to strengthen it — this is one example of a simple modification of the outside contour. Obviously in such composite structures the design must be properly considered and the welding done by best approved practices.

Many mechanical and structural members may be fabricated wherein tubular sections are welded to statically cast parts of irregular form. An example is the radiant tube heater, where sand cast return bends are welded to centrifugally cast tubes, forming a U-shape. Conveyor rolls used on heat treating and sheet normalizing furnaces are made by welding a large diameter roller to smaller diameter bushings at either end with hollow sand cast cones forming the transition. Valve seats and hollow shafting are among the many other products.

Since the announcement of the early commercial machines by De Lavaud, Millspaugh and others during the period of 1912 to 1916, many modifications and improvements in design and operation have been made for the purpose of overcoming certain mechanical or metallurgical difficulties. That the various modifications of the early process ultimately evolved have proven of definite economic value to industry is attested by the large annual tonnage of various products made in this manner. It does not seem too much to expect, therefore, at the present time, that research and development in progress on the application of centrifugal casting of high alloys will effect further substantial economies and definitely widen their field of usefulness.

Distribution of Phosphorus Between Steel and Slag

By E. Maurer and W. Bischof

Condensed from Journal, Iron & Steel Institute

PROBABLY the phosphorus occurs in molten steel as a phosphide of iron and manganese, and its transfer to the basic slag is as follows: Phosphide is oxidized by dissolved ferrous oxide to P_2O_5 and this combines with more FeO to form iron phosphate. The latter passes into the slag, where, in the presence of lime, it is converted to a more or less stable calcium phosphate.

Several attempts have been made by us and others to use the above reversible reactions, but the absence of exact knowledge about the forms taken by the reacting substance has prevented any useful application of the law of mass action. We postulate, therefore, a simple relationship between P_2O_5 in the slag and the phosphorus in the steel, both expressed as weight per cent: $R = P_2O_5 \div P$.

We have assumed that this ratio R, as it varies from time to time in the making of a heat of basic steel, tends to adjust itself in the direction of equilibrium; hence if steel and slag are sampled at intervals, the changes in the ratio will show the direction in which equilibrium is to be sought—on condition that no additions have been made in the interval and no very *pronounced* change in the other slag components.

Abundant analytical data of this kind are available in the literature and from our own studies. We have taken into account only those in which phosphorus has been accurately determined to within 0.001%. The mean temperature is taken at 2900° F. (1600° C.) corresponding to that which may be expected in the final period of the basic open-hearth process. Experimental melts guided the analysis of operating data.

For instance, the effect of changes in manganese in the steel is known to be important. Numerical data plotted in the upper left corner on page 49 show that an increase in manganese (composition of slag remaining constant) results in an increase in the phosphorus content of the steel. The figure is also useful in order to find the theoretical phosphorus in the steel when manganese is nil, regardless of the composition of the slag. Suppose the steel analyzed 0.038% P and 0.40% Mn (point *A*). Running down an interpolated curve to 0.0% Mn gives 0.026% P (point *B*), which we *(Continued on page 70)*

Special Methods of

GAS FIRING

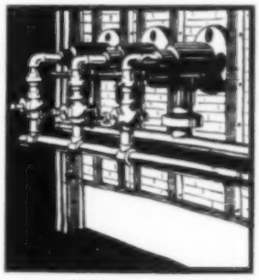
to Avoid Scale and Soft Skin

AN IMPORTANT CHANGE in the method of firing the billet heating furnaces at the Columbia Tool Steel Co.'s plant in Chicago Heights, Ill., is regarded by the management as the greatest forward step in the tool steel industry in recent years. Not only has there been an improvement in operating schedules and a greatly reduced loss in scale, but most important is the increased quality in the finished product.

Gas has been used as a fuel for forging furnaces with varying success at various places in the United States during the past 50 years. As a fuel alone, it showed some superiority due to its greater ease of control, but it was not until the problem was approached from the angle now to be described that the full advantages of gas were realized. Success of the present installation is based on the new conception that gas is a valuable metallurgical reagent in addition to a source of heat. Robert G. Guthrie, chief metallurgist of Peoples Gas Light & Coke Co., (and past president of American Society for Metals) and his associate, O. J. Wilbor, have been developing and experimenting with this idea for a number of years.

By Winfield Foster
Peoples Gas Light & Coke Co. . . . Chicago

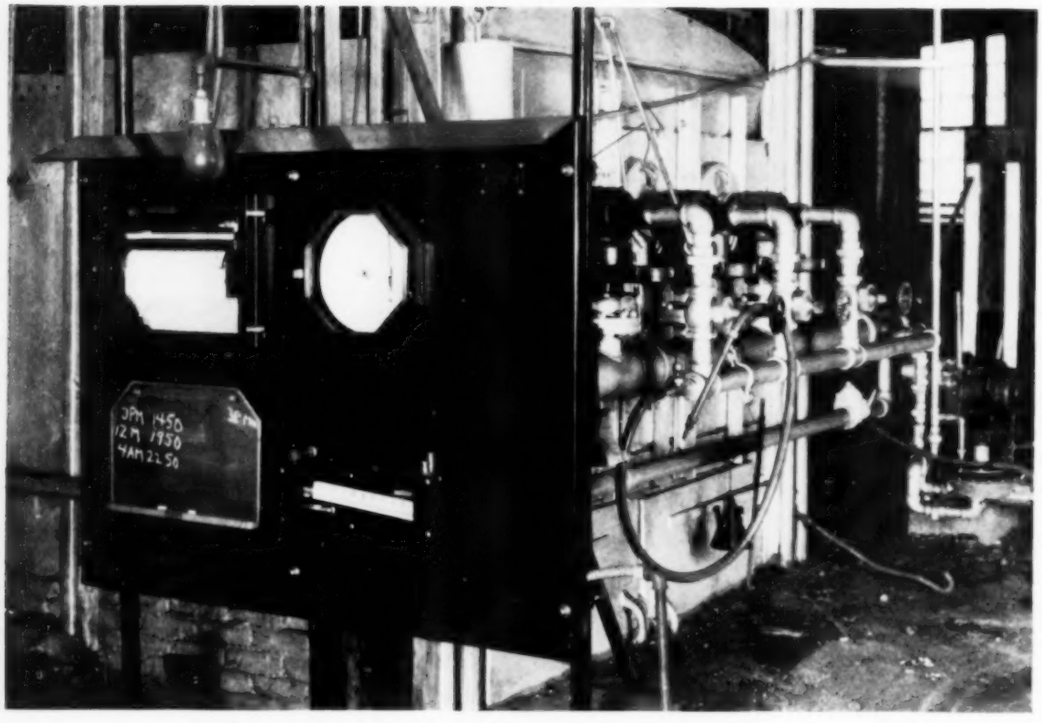
The installation at Chicago Heights now comprises four billet and bar heating furnaces, with hearths up to 16 ft. long by 7 ft. wide, and with capacity up to 20,000 lb. per charge. Conversion from coal-fired hearths was not a very complicated matter: The furnaces were redesigned and linings rebricked to satisfactory dimensions and conditions for gas firing, flue vents were installed in place of stacks, and fireboxes bricked over.



Each furnace is equipped with three Mahr low pressure sealed-in burners, each having a capacity of 2100 cu.ft. of 1000-B.t.u. natural gas per hr. The design is rather special and each burner is mounted in a proper combustion chamber. Air is supplied to each from a blast main leading to a blower, one for each furnace. The control required that each furnace be equipped with two-position proportioning valves on gas and air lines, with mechanical linkage and electrical operation. For this purpose a North American motor-operated valve was selected. A general view of piping, blower, and valves is shown on the next page.

Interest in the installation is centered about these controls, for it is on their efficiency that success is based. In contrast with traditional practice, the instruments are set close to the furnace and in full sight of the hammer crew, instead of being mounted on a central control board or in the superintendent's office. In addition to the usual recording temperature controller, and gas and air regulating valves, the controls include a continuous gas analyser and recorder for each furnace, accurate pressure gages, and gas pressure regulators.

An interesting feature of the arrangement is that the foreman of the hammer crew determines the 24-hr. heating program. A typical program for the night hours, for instance, will run as follows: 11 p.m. set for 1450°; at 3 a.m. set for 1950°; at 5 a.m. set for 2300° F. This provides hot billets at full temperature (2300° F.) when the crew arrives for the day's work.



Remodeling Job on Billet Heating Furnaces Cuts Scale Loss and Decarburized Skin on Tool Steels. Gas burners are controlled by recording pyrometer. Instrument panel also contains pressure gage, flue gas analyzer and instruction board for heaters on other shifts

At the hours designated, the night men set the temperatures on the controllers. The foremen can satisfy themselves by a glance at the recorder that the program was followed and that the material is ready and in the best condition for working. This practice not only assures accurate temperature control, but controls the heating rate, with definite starting and finishing temperatures.

The controlled *atmosphere* in the furnace, free from outside variables, plays an even more important role in assuring the quality of the finished work. In these reconditioned furnaces decarburization of the surface has been reduced about 66%, and scaling has been reduced about 75%. The scale that comes off at the first hammer blow is paper-thin. Previous losses, from ingots to finished bars, had run as high as 9.4%; much of this is now recovered in salable weight.

Another important advantage lies in the uniformity of the product from heat to heat, day to day, season to season, and year to year. Thus, the fact that there is no stack in connection with the furnaces, and therefore no inflow of draft around furnace doors, prevents any chilling of billets at the door end. Actually, one of the most important features of the entire design — the feature which makes possible all the control and uniformity — is the use of a relatively high positive furnace pressure. Operation of the furnace is therefore entirely independent of outside weather conditions. This positive pressure prevents any influx of air into the furnace, (even though a curtain of air is provided by blowers and piping in front of each furnace door — by this means a thin sheet of air protects the workmen from an excess of convected heat).

Among the collateral advantages of gas firing are improved working conditions for the hammer crew, no smoke, much greater cleanliness, and better illumination of the shop.

Firing speed has been increased about five times, which is an important item; even so there is no danger of overheating the work. Furthermore, under-heating of work with improper finishing temperatures and their ill effects have been eliminated. The thermal efficiency of the furnaces was increased approximately 50% by elimination of stack and infiltration losses.

Overall Economies

Many old-line forge shops and rolling mills are ankle deep with scale. An equal amount of oxide has probably dripped off into the furnace hearths, to their ruination. Scale is just so much lost metal — to say nothing of its abrasive action on expensive forging dies. Likewise decarburization proceeds about as fast as scaling. Lost metal and soft skin are equally objectionable to the more expensive alloy and tool steels, and a firing method which cuts these losses down to a minimum certainly deserves the praise which the Columbia officials give it. It is indeed another forward step toward perfection in the fine and ancient art of making tool steels.

Uses and Limitations of the

SPECTROGRAPH

for Industrial Control

SPECTROGRAPHY, the science of detecting and measuring the elements by means of their light (given off under proper conditions of excitation), is by way of becoming an art. Well known for years to the astronomer and physicist, this instrument in its newest form is rapidly being taken up by plant laboratories as an indispensable piece of apparatus for the analytical chemist. In fact it is essentially the industrial chemists — metallurgical, biological, food and agricultural chemists — who are furnishing the present impetus. It is the chemist, pressed as he is for greater precision, speed and lowered costs, who is realizing, if somewhat tardily, the possibilities of the spectrograph for quantitative work as well as qualitative analysis.

This by no means is meant to infer that all the scientific kinks have been straightened out. Far from it! Results of excitation vary and the cause is not always understood nor within proper control. Sensitivity of an element may vary under dissimilar occurrence and a seemingly similar procedure, which is another way of saying that the sensitivity of an element may be affected by the presence or absence of another. Methods of measurement of the spectra vary, too, but proper control will be best perfected under scientific auspices rather than trial and error or rule of thumb.

Over-enthusiasm, however, must be guarded against. The spectrograph is not a cure-all and exaggerated statements, sometimes made as to precision, speed, sensitivity and low cost must be accepted with more than a grain of salt. Those of us who have had a number of years experience with this new tool of the analyst and are therefore in a position to be somewhat conversant with its many possibilities, would be the first to decry unsupportable claims of too general a nature; there are plenty of worthwhile examples of all the factors just named without resorting to exaggeration. In most cases such rosy views are born of either over-enthusiasm or insufficient experience with industrial problems. At any rate, here as in many other scientific instances, understatement rather than overstatement is preferable and indeed at times inspires the necessary confidence.

On the other hand, others frightened by the first cost of equipment and perhaps discouraged by a wrong application carry the misconception that it is purely an academic or research instrument and not for practical use.

As a rule the industrial spectroscopist uses the quartz prism rather than the grating type of instrument and studies emission spectra rather than absorption, for the detection of metals is the peculiar field for which it is thus most applicable. Of course there are limitations, which will be discussed here. Certain of these limitations refer to the instrument and others more often to the application and present knowledge of proper technique. For example, it would often be desirable to get further down into the ultra-violet rays (that is below 2200 Å units); less often wave lengths above 7000 Å, the usual range, up into the infra-red section would be useful. Progress in extending the useful band of wave lengths must continue to arise out

By Thomas A. Wright
Technical Director
Lucius Pitkin, Inc.,
Consulting Chemists
New York City

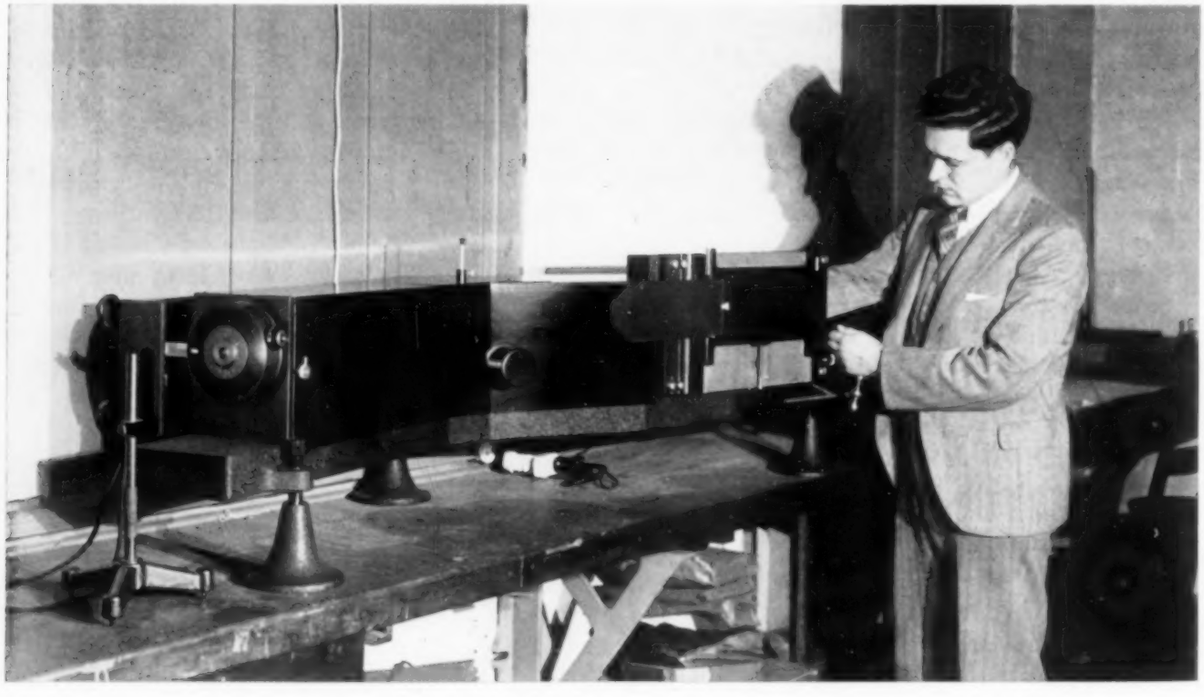
of a basic and scientific attack of the problem of photographic reproduction. "Needs must, needs can," and the economic urge will no doubt accelerate the needed improvements with continued and widened every-day application.

Metals after all are rather ubiquitous (one might almost say gregarious) and it is in the detection of metals and their comparative, relative or quantitative estimation that emission spectrography finds its present greatest application — metals present, that is, by "happenstance," from contamination or from intended additions. Fair approximations of alloyed constituents even up to say 5% can often be most expeditiously, conveniently and cheaply made. For quantitative work most workers use it primarily in those cases where a precision of one-tenth to one-fifth the amount present will suffice or excell other methods.

Micro-analytical work, on the other hand — another new development engaging the respectful attention of the thoughtful chemist — is perhaps best applied to the determination of major components in minute samples, and then most often to organic work and for elements either not within the field of emission spectrography or less definitely so. Contrariwise, industrial spectrography is usually applied to the determination of minor components in either minute or large samples, but it is a mistaken idea that its use is confined to amounts less than those within the province of ordinary gravimetric analysis. For instance, certain refined metals could often be best graded by spectrographically determining or estimating the metallic impurities. Gold and silver offer two excellent examples; their impurities are primarily of a metallic nature, and can be separated and determined in other ways known to the assayer. Copper would be a poor example for spectrographic study due to the importance of three non-metallic elements invariably present — oxygen, selenium and sulphur. Selenium, of long interest to the copper metallurgist, of more recent interest to the steel maker and the agricultural chemist, may not be estimated or even detected by the arc-emission procedure such as is now commonly employed.

Metalloids in general are not as sensitive as metals; that is, more of the element must be present to give lines of sufficient intensity, depending on the instrument used. The sensitivity of instruments varies, this factor being sacrificed in the larger instrument for the sake of greater dispersion, that is a longer spectral band.

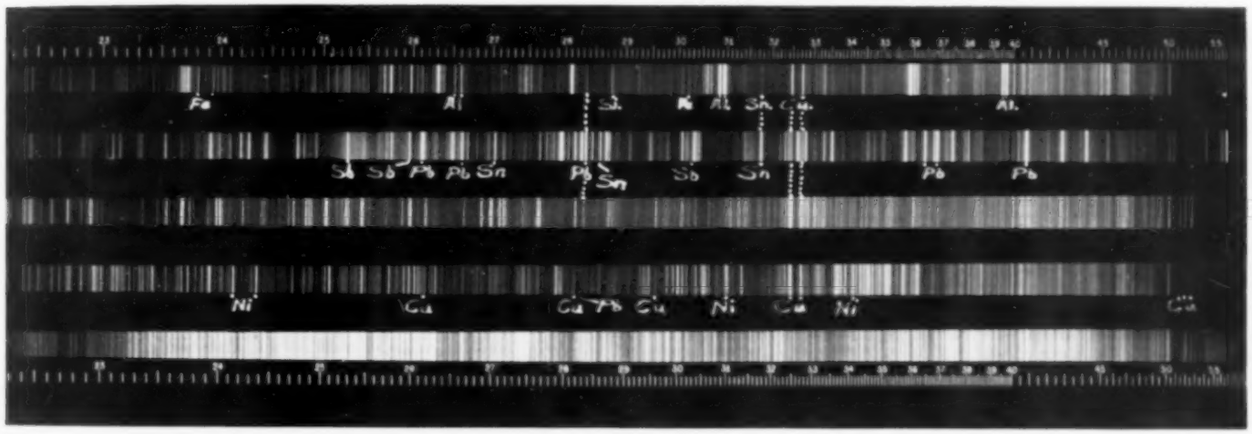
Almost without exception the spectral photographic evidence is in the form of a line, the



"It is a curious fact that no one can work long with a spectrograph without becoming fascinated with its possibilities," writes Prof. W. J. Crook in the preface of his Atlas of Metallurgical Spectra. Photo is of medium quartz spectrograph; this and others by courtesy of Bausch & Lomb Optical Co.

opacity or blackening of which increases with the amount, although not necessarily directly proportional. When cyanogen is present, as it is when a graphite electrode is used, its presence in the arc results in bands which may mask the lines of certain elements. Lines represent the atomic spectra and bands the molecular spectra; hence the latter appear again when calcium and fluorine are both present, and advantage is taken of this in examining waters for fluorine.

The growing industrial influence of the scientifically educated and trained chemist and metallurgist is no doubt responsible for the growing appreciation of the part played by minutae in alloys. Someone has recently termed these "cryptotrophic elements." For example, those studying animal and plant nutrition, food and soil chemistry are more and more aware how very important a part minute amounts of metal



may play in metabolism, or influencing a flavor or a color. These small amounts may at times be toxic, they may be directly beneficial or catalytic in their action and effects. Such infinitesimal amounts may occur naturally, absorbed from the soil, or they may occur, as in the food or chemical industries, by way of corrosion of process equipment or container, or by introduction of formula or process chemicals.

In any event, they are important to producer of metal and alloy, to fabricator or worker, to producer of chemicals and to user alike. No one of these groups can afford to disregard the necessity of his fellow; hence the metallurgical chemist and metallurgist may be especially interested in detecting and determining these small amounts. A mickle to the one may be a muckle to the other. Steel metallurgists have been rarely concerned with constituents present in amounts less than the second decimal place, but copper refiners may need to watch the third and also the fourth. Food chemists, pathologists, physiologists, toxicologists and biologists are generally interested in and refer to metals in parts per million, — at times, as with the toxic elements lead or thallium, in decimal parts per million or even per billion!

Manganese in increments ideally within the scope of spectrography is added to fertilizer as a plant stimulant. When present in a hard rubber storage battery separator it is said to be the cause of brittleness and must be closely determined and controlled. Absent from the diet of a rat, fecundity, of even such a prolific animal, is said to cease. Bismuth above the fourth decimal place is anathema to the copper wire or rolling mill, while electrolytic bismuth substantially free of silver was reputed to be unsatisfactory for the production of the type of bismuth sub-nitrate crystals thought purest by the druggist.

"Purity" and "quality control" in fact are terms that immediately crop up in any discussion of the spectrograph. One brings to mind the other. This is particularly true of the nonferrous and certain of the precious metals — silver for sometime past, gold more recently, zinc and cadmium of course. Reference has already been made to oxygen, sulphur or selenium in refined copper as not within the scope of present-day spectrography, and arsenic below the second decimal place is not within the range unless by prior concentration.

As a matter of fact, references to amounts detected expressed in per cent are often times erroneous and misleading. The spectroscopist is

not so much interested in the percentage as he is in the actual concentration, and it is often necessary to isolate or concentrate the elements by chemical means, before the amount of the substance present is within the sensitivity limits of the spectroscope.

Spectrography of iron and steel has lagged behind, possibly because the iron group furnishes such a multitude of spectral lines that the largest or Littrow type of instrument is advisable for its greater dispersion — notwithstanding the somewhat lessened sensitivity. Less expensive and smaller prism instruments have been recently developed, and are now available. These small types (especially is this true of the intermediate type) are quite suitable for some non-ferrous metals and may even possess certain other distinct advantages. For example, it is necessary in making a so-called "complete examination" with the Littrow instrument, to take spectra in three or four different wave-length positions. Only one position would give the entire working range with the intermediate type, but the ferrous metals would possibly offer more chance of conflicting or coincident lines.

The growing call for information as to the possibilities of spectrographic analyses was very evident at the three lectures given by E. J. Martin at the Chicago Convention, and at a recent meeting of the American Society for Testing Materials, where a spirited and pertinent discussion was held on the methods for steel, nickel alloys, the platinum group, magnesium base alloys, refined cadmium, cadmium bearing metals and cadmium compounds. Of still greater purport was the acceptance, as tentative standards, of three analytical methods for refined zinc, zinc base die cast alloys and certain grades of pig lead. The frailties of chemical analysis of die cast alloys have become more and more apparent — as a matter of fact, the zinc and aluminum alloys are excellent examples of the spectrograph's value.

Some eighty or more installations of the quartz spectrograph have been made in about two dozen industries in the United States, if our data are correct. Since the early routine commercial use by William H. Bassett and C. H. Davis the field has rapidly widened, particularly in the last five years, so that now we find high grade work in the electrical, radio, explosives, rubber, heavy chemical, pharmaceutical, glass, petroleum, food, battery, plastic, photographic, container, refining, smelting, automotive and public service industries. At least eleven electrical, fourteen non-ferrous and eight ferrous laboratories are using the spectrograph as a technical routine tool as well as a scientific instrument. It may be on the rubber separator or lead-antimony grid of the storage battery, the radiator solder, a bearing metal, the aluminum piston or zinc base die casting of the automotive industry. It may be the cable sheathing or the copper conductor of the public utility or electrical plant or the fusible alloy of the fire detection system. Or it may be one of innumerable cases of trouble-shooting or exploratory studies in foundry, mill or any other metallurgical field.

Possibly a rapid glance over some of the non-confidential items from the file of an independent consulting and testing organization should give an excellent idea of the daily applications. Titles so chosen at random from reports essentially spectrographic in nature are given below, but there are many other cases where this examination is but one and perhaps an incidental or even minor phase of a project in which metallographic, petrographic or microscopic work may be as necessary as precise analytical chemistry.

Corrosion of metals — coated and uncoated.
Sea-water damage.
Galvanized and tin plate.
Metal pickup or inherent in industrial waters.
Pickling stains on brass.
Suitability of containers.
Intermediate or surface electroplates.
Deposits in tubes and apparatus.
Foils and tubing.
Smoke nuisances, dusts, fumes, soot.
Fires and explosions.
Insurance, compensation and casualty.
Fertilizers and soils.
Food processing equipment.
Lead poisoning.
Lead in tea and cocoa.
Metals in beer (copper, iron, lead, tin, silicon).
Cancer research.
Medicinal solutions.

Comparisons of various brands, grades and refining stages of aluminum, bismuth, antimony, tin, zinc, lead, carbon and the precious metals, new and old production, may all be quickly and cheaply made with confidence for increases, decreases, appearances or disappearances of impurities or alloy additions. Other examples are given herewith as further illustrating the fields:

Purified nickel — vapor contamination.
Radio tube filaments and failures.
Surgical bulb failure.
Contaminated thermocouple (platinum-rhodium).
Surface defects of duplex-plate.
Complex ores and concentrates.
Purity of laboratory precipitates.
Purity of assay beads.
Good and faulty copper sheet.
Lead sponge.
Engravers zinc, defects in.

Conformity to government specifications.
Identification of mixtures, ashes and residues.
Ancient coins and bronzes.
Gasoline.
Homicides — forensic analysis.
Ceramics and pigments.
Rare metals; dental alloys.
Cast iron and ferro-alloys.
Hardeners, deoxidizers and fluxes.

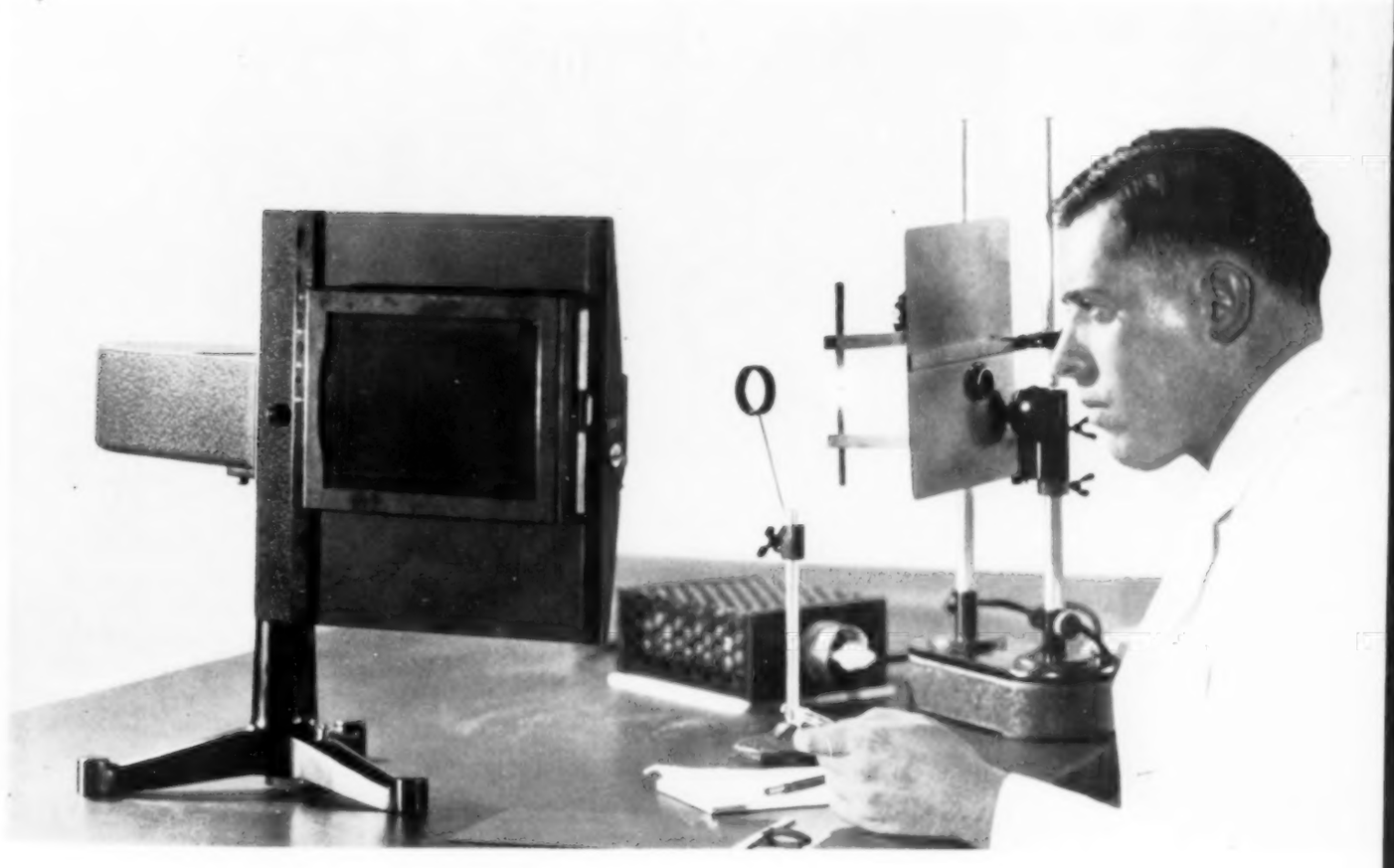
Spectrography then is not a fad, despite the recent mushroom growth. Nor has the widespread use been essentially because of greater opportunities of lowered analytical costs — low despite the initial cost of the apparatus and the greater cost of accumulating sufficient experience. The cost is a variable and must be considered with all the other factors, such as required precision. Spectrographic analysis may, therefore, be cheaper or it may be much more expensive.

While savings often accrue in time and money, the major urge appears to have been the real advantages offered in precision and certainty, within the scope described. It is well to emphasize that chemical analysis, itself, has certain very definite limitations, some of which are not appreciated, some of which may be overcome and eliminated, and some minimized by the use of spectrography.

Reference has been made to the limitations of spectrography. Sanely developed through the cooperation of the analyst, the metallurgist and the physicist, more and more instruments will be installed. The widening of the field will come as spectroscopists contribute to the literature and discussions, and as industry presents its problems for consideration and study. It is certainly true that one can, under certain limited and special conditions, get certain limited results which are badly needed and are valuable at that. Too much emphasis on low costs and speed, however, is placed by those enthusiasts and purchasing departments whose criterion as to service is price.

No chemist who is worthy of the designation "progressive" (and the same applies to the metallurgist) can afford to ignore spectrography. It is not only going to find new application but it is quite likely going to result in new ideas and open up new fields for metallurgists and engineers as well as biologists, physicians, physicists and astronomers.

Small Littrow Spectrograph



OUR BIOGRAPHICAL DICTIONARY

Blank & Stoller

GUILLIAM H. CLAMER

OF EMINENT LIVING METALLURGISTS

In the 1870's the American railroad industry, then about 40 years old, was just beginning to find that some of the tried and true materials were not good enough for the required duty. Bessemer steel rails had vastly improved the road bed but rolling stock was none too good. Hot boxes were proverbial causes for delay.

During that decade a Philadelphia inventor named Francis J. Clamer developed a radically new "bearing bronze," containing lead in addition to the copper and tin. This soft metal in a harder matrix maintained an oil film better, and the rate of wear decreased and frictional losses (operating temperature) lowered. This new alloy formed the basis of the Ajax Metal Co.

The producer of the new leaded bronze alloy had a son who was sent to the University of Pennsylvania, where he studied chemistry and what "metallurgy" was then taught. In 1896 Guilliam H. Clamer was employed by his father's firm and started what was probably the first metallurgical laboratory in an American plant making non-ferrous alloys. He learned that Dr. Dudley, head of the testing department of the Pennsylvania Railroad, had found that it would be desirable to put still more lead into bearings. Young Clamer went at the problem with youthful enthusiasm and found a way to produce "plastic bronze" bearings containing more than 15% lead, at the same time reducing the expensive tin content, on which he was awarded a patent at the age of 25.

The following years saw the introduction of manganese bronze jointly by the Ajax Metal Co. and the Wm. Cramp Ship and Engine Building Co. The latter company operated under the Parsons patent, of English origin. The brothers Cowles, of aluminum reduction fame, had taken out a patent on the use of aluminum, and its use as an essential element in manganese bronze was quickly recognized by the young chemist.

In this work Clamer realized the absolute necessity for chemical control in the brass and bronze foundry, yet knew that very few plants of the day could keep a chemist busy. He therefore proposed to market metal ingots, which, when melted in ordinary crucibles, would produce castings of certain widely accepted analyses. Proper melting furnaces and refining technique enabled him to utilize in this way a considerable amount of selected secondary metal as satisfactory raw material.

He later developed a method for refining scrap metals based on the fact that the metals classed as impurities in a copper-tin-lead alloy (namely zinc, aluminum, iron and silicon) may be used as reducing agents to separate copper-tin-lead from their oxides or salts. At that date large tonnage of copper oxide was available in the form of scale from copper rolling mills. Lead and tin were also available as by-products in the form of drosses. It was possible by this method, therefore, to eliminate undesirable constituents of an alloy and at the same time utilize by-products. For this achievement the Franklin Institute awarded him at the age of 28 the Elliott Cresson Gold Medal, its highest award.

However, it was in the development of electric furnaces that his mettle was really tried. "It was in 1911 that I first became interested in electric melting furnaces," writes Dr. Clamer in a recent article. "I was at that time working on a research problem, the solution of which seemed possible only through the use of an electric furnace. That particular problem is, however, still unsolved, although I am today nearer to solution of it than I then was . . . I am a firm believer in the fact that great progress is made by making mistakes and by encountering difficulties."

One cannot help thinking of the insight into the man's character these words give. Dr. Clamer modestly gives credit to others for the ideas leading by painful expensive steps to final success, but the fact attested by his many friends and associates is that success was essentially due to his wise and kindly guidance and never-say-die backing. Let us recount, briefly, the history:

Dr. Carl Hering, a well-known electrical engineer, had discovered the "pinch effect," whereby molten conductors contract in cross-section, even entirely separating when conditions are right. About $100,000 was spent by Ajax Metal Co., together with Scovill Mfg. Co. and National Cash Register Co., in an attempt to use this pinch effect to heat and stir a molten bath. The resistors were built in the furnace bottom, so that the hydrostatic head could instantly supply metal to them, but they could not be made tight. Eventual success came through the suggestion of James R. Wyatt, a member of the staff under Dr. Hering, that alternating current be induced into a submerged loop of molten metal by linking it through a built-in transformer, thus eliminating the troublesome electrodes.

This became the Ajax-Wyatt furnace. (The first of these was bought by Bridgeport Brass Co. in 1917, six years after the development began.) It has proved so satisfactory that about 95% of the crucible furnaces formerly used for melting in all the American copper and brass mills — as

distinguished from foundries—have now been replaced. It has been proclaimed by a leading manufacturer of wrought brass as the greatest single development in the brass industry during the past 140 years!

E. F. Northrup of Princeton University had been a consultant during the above developments, and when they seemed well toward success (1916) Dr. Clamer asked him to review the theoretical possibilities pertaining to conversion of electrical into heat energy. After careful study Dr. Northrup said that there remained but one basic principle left for investigation. This was the use of high frequency current in an induction furnace with a crucible shaped hearth. An enormous amount of work had been done on wireless, but the effort had always been to increase the voltage and frequency for more distant transmission. Evidently no one had thought of using low voltage, high frequency current for heating.

Clamer at once authorized experiments on a small scale to determine the feasibility of the new ideas, and Northrup set up his first home-made apparatus in the Palmer Physical Laboratory at Princeton. Here Dr. Clamer journeyed repeatedly and saw apparatus of considerable bulk energizing a small induction furnace coil which would melt only a few pounds of tin! He heard the report of one of the most prominent electrical engineers of the time to the effect that the high frequency furnace could never be anything more than an interesting toy. A little later, with somewhat improved apparatus, it was possible to heat 5 lb. of 6-penny nails to such a temperature that they would weld together into a porous mass.

Clamer and Northrup with their enthusiasm and vision made an unparalleled team. Dr. Northrup had the scientific background and time necessary for the development and Dr. Clamer the technical ability and cash resources. To try to determine whether the one or the other played the more important part is as futile as the old argument as to which really came first, the chicken or the egg.

By the end of 1917 two of the new furnaces had been sold, one to the Corning Glass Co. and the other to Baker & Co., where the late Edward A. Colby had long before tried to make a practical high frequency furnace for platinum melting. However, the steady stream of expense for development continued; probably $250,000 had been spent before any return on the investment was in sight.

Difficulties centered about the equipment (then undeveloped) for production of power of correct characteristics. Eventually came the development of the mercury gap rectifier and proper capacitors. Tests made in 1923 at National Machinery Co., Tiffin, Ohio, proved that medium frequencies of 500 to 2000 cycles would be suitable for steel melting, and General Electric Co. shortly thereafter built rotary converters for this service. With adequate sources of power from rugged machinery, the success of the high frequency induction furnace was assured.

Probably its first successful application to commercial melting was by Robert H. Leach of Handy and Harmon Co., Bridgeport, Conn., who has used it ever since for melting sterling silver. Babcock and Wilcox Co. made the first installation devoted to steel; American Brass Co. to copper alloys.

In technical as well as business matters Dr. Clamer shows genius of a high order. His clarity of thought and ability to see to the heart of a matter, as well as his quickness of decision even in complicated dealings, are constant sources of gratification to his associates. And speaking of associates, there is no man more respected, admired, and held in honor by those about him. One remark illustrates the attitude of all of Dr. Clamer's associates: "I do not work for Dr. Clamer, but with him." He is even-tempered amid conditions which would throw most men into heights of exasperation. Men go to him with quarrels and come away feeling friendly.

In the midst of his busy life he served the government in various advisory matters concerning metals during the War. He also served as president of the American Foundrymen's Association, president of the Institute of Metals, and president of the American Society for Testing Materials. In these organizations his interest is unceasing. He has for 30 years been a member of the Committee of Awards and Board of Directors of the Franklin Institute. He was a charter member of the Electrochemical Society and one of the first American members of the British Institute of Metals. He has also maintained membership and interest in the American Institute of Mining & Metallurgical Engineers, the American Institute of Electrical Engineers, the American Society for Metals, and the Britsh Iron and Steel Institute.

All his friends were delighted to learn of two recent honors bestowed upon him, the degree of Doctor of Science by Ursinus College, and the Joseph Seaman Gold Medal of the American Foundrymen's Association, both for his outstanding achievements in the casting industry.

DUDLEY WILLCOX

Interesting Items in

LETTERS

from Here and There

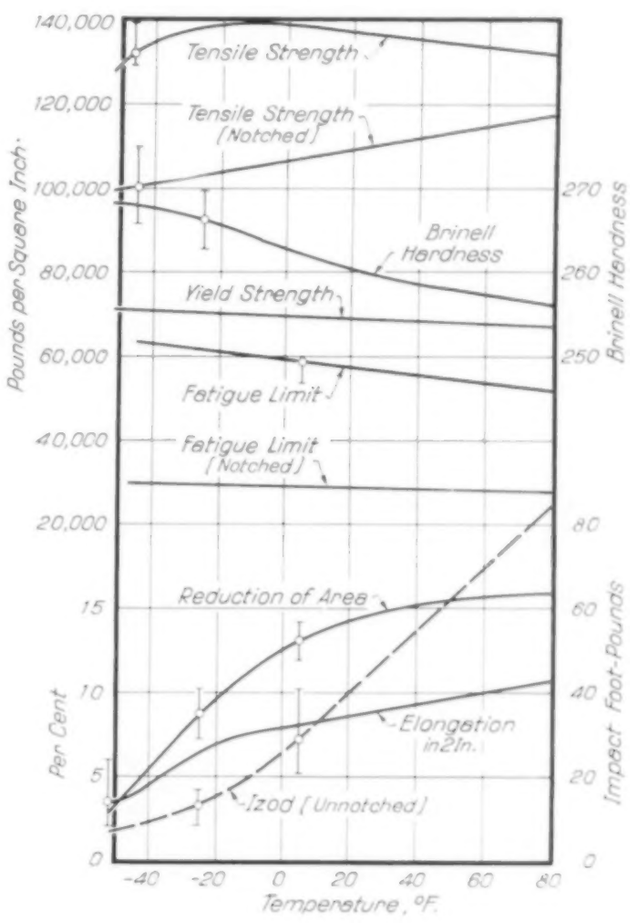
Properties of Rail Steel at Arctic Temperatures

URBANA, *Ill.*—It is a matter of common railroad experience, especially in the northern United States and Canada, that rail failures are more frequent in cold weather than in warm weather. Two general types of explanation for this have been offered: *(a)* Changed track conditions due to low temperatures and to freezing and thawing, and *(b)* changes in the physical properties of rail steel at low temperatures. In an attempt to determine the facts as to the second explanation a fairly extensive series of tests has been made in the cold room at Wright Field, Dayton, Ohio, with the very generous aid of the U. S. Air Service and especially of J. B. Johnson, chief of the materials laboratory at Dayton.

This work was done in connection with an extensive investigation of internal fissures in railroad rails organized in 1931 under the auspices of the Rail Manufacturers' Technical Committee and the Association of American Railroads. These two cooperators asked Prof. H. F. Moore of the Engineering Experiment Station of the University of Illinois to direct the investigation. A bulletin covering the findings has been published and abstracted in METAL PROGRESS last November. Additional data are summarized below; the undersigned conducted the tests at Wright field.

Fatigue tests, tensile tests, Brinell tests, and impact tests of numerous specimens from three rails have been run in this cold room with minimum temperatures of —40 F. for all tests and of —53 F. for impact tests and tensile tests. Standard specimens and notched specimens were both used. In the diagram of results the spread is shown where there is not first-class agreement.

It will be noted that the tensile strength of unnotched specimens increased as temperatures decreased to about zero Fahrenheit, and then decreased with further decrease of temperature for steel from two rails and increased in strength for the steel from the third rail. Notched tensile specimens showed decrease of strength with de-



crease of temperature. Brinell hardness increased with decrease of temperature. Fatigue strength of unnotched specimens increased with decrease of temperature, while fatigue strength of notched specimens changed but little with decrease of temperature. At the lower temperatures the rail steel tested seemed more sensitive to effect of notches than at higher temperatures.

The figure also shows the results of the tests for ductility and impact value. Elongation, reduction of area, and (most marked effect of all) Izod value for unnotched specimens, all show marked decrease for lowering of temperature. Olsen-Izod tests on notched specimens were very low; about 2.5 ft-lb. at +70°, 2.2 ft-lb. at zero and 1.5 ft-lb. at —50° F. The exact significance of the results of impact tests of specimens is still a matter of considerable uncertainty. However, a high impact strength is a point in favor of a steel, and a lowering of impact strength indicates some type of damage.

Of the three rails from which specimens were taken, one was a rail cooled on the hot bed in which etch tests had shown shatter cracks, another was a companion rail slow-cooled in which no shatter cracks had been found, and the third was a hot-bed-cooled rail in which etch tests had shown no shatter cracks. No outstanding differences appear between the results of strength and ductility tests for these three rails.

To sum up, definite evidence has been obtained that the general tendency is for strength properties of rail steel to increase as temperatures decrease to —40° F., while the brittleness of the steel also increases. A series of fatigue tests to study the weakening effect of occasional periods of overload would be rather time-consuming and expensive but would seem very worth while.

H. B. Wishart
W. D. Boone.

Ethiopian Blast Furnace

Columbus, *Ohio* — The two photographs herewith will be interesting to many, as a surviving example of primitive iron smelting methods. They were taken in Central Africa by W. E. Thorne, a distinguished mining engineer whose headquarters are in London. The barren landscape has little suggestion of jungle; the location is on the plateau south of the eastern end of the Great Sahara, near Lake Chad. The product is a good grade of charcoal iron; operations are intermittent — according to Mr. Thorne about two weeks' work by the party will get enough iron for the tribe for a year.

The site chosen is one near ore deposit and forest where there is a considerable mass of tufa, a soft calcareous rock deposited from spring water. A block of it will be cut so it has vertical front and rear faces and a series of horizontal holes tunneled through for blast pipes.

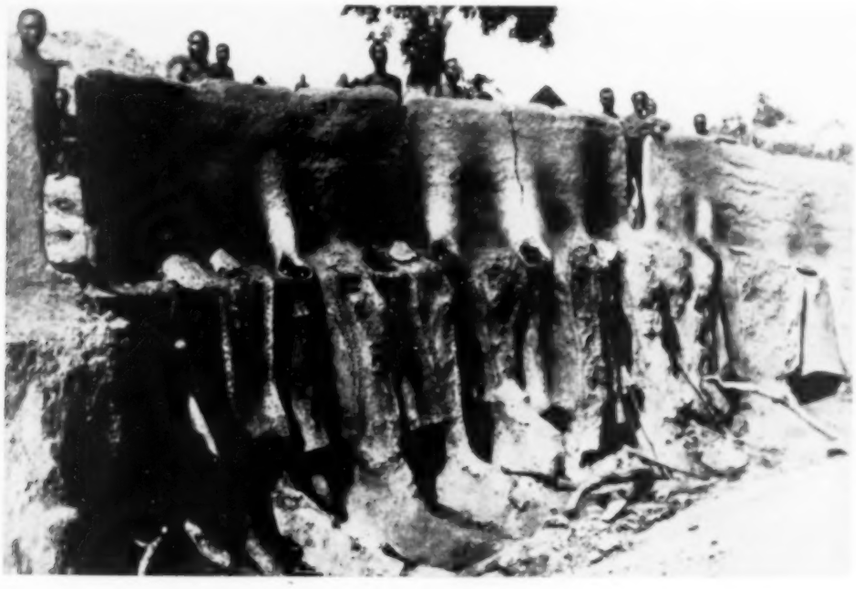
The "boy" at the left foreground of one photograph is making a tuyere for conducting air from the bellows to the bottom of the furnace shaft. He first lays out a grass mat on the ground, plasters it with mud, rolls it on a 4-in. tapered stick, again plasters it with mud, then stands it on end until dry. The tuyere is placed in the tunnel, the stick withdrawn, and connection made to the bellows at the back end of it and to the

Central African Blowing Engines Consist of a Pair of Bellows Alternately Pumped by Sticks in Right and Left Hand; Shifts Change Frequently

furnace shaft at the front.

The shaft is about 15 in. diameter and is built into vertical channels cut in the rock breastwork. The lower part is closed by a temporary wall, and the shaft filled with charcoal and ore, with a little fine limestone. When most of the iron is reduced and slagged, the breast is broken open, the charge removed from the bottom of the shaft and lumps of iron recovered.

Methods such as these are widespread in Central Africa. One of my friends recently saw some movies taken in Belgian Congo and Northern Rhodesia, which show me that the natives in that region also use the "direct reduction" process of iron from ore. It is interesting to speculate on the origin of this art.



Primitive Iron Furnace Is a Shaft, About 15 In. Dia., Built in a Channel Cut in Soft Stone. Air Is Blown Through a Tuyere in a Hole Near Bottom, Cut Through the Stone Breastwork to the Rear. A lump of reduced iron is taken out of the door at bottom and hammered to shape. Photos by W. E. Thorne, near Lake Chad, south east of the Sahara Desert

Mr. Thorne notes that the "student club" haircut was not imported from an American campus (or vice versa). The type of head-dress varies from tribe to tribe and is a burgee or gonfalon wherewith to recognize friends and neighbors at shooting distance.

W. J. McCaughey

Heat Resisting Cast Irons

Birmingham, *England* — Professor Portevin, in a communication in your issue of November 1935, says that success in evolving heat resisting steels achieved by adding chromium, silicon and aluminum, should lead to the application of the same principles to cast iron. After discussing the main differences between steel and cast iron, the inference is made that two classes of cast irons would probably be resistant to chemical action of hot furnace gases, one being the silicon and silicon-aluminum cast irons. It might be inferred from this note, that prior to the investigations of Thyssen, described in the British Iron and Steel Institute Journal, 1934, previous attempts to combine these elements had not been successful. Thyssen gives silicon 5.5% and total carbon 2.5% as the best combination of these elements.

I take this opportunity of pointing out that the 5.5% silicon, 2.5% carbon heat resisting cast irons, known as "Silal," and containing up to 10% aluminum were worked out in the laboratories of the British Cast Iron Research Association by Norbury and Morgan, and covered by British Patent 323,076. They were first reported to our members in 1929 and described to the British Iron and Steel Institute in the *Journal*, 1932, No. 1, p. 402. Subsequently the high silicon austenitic cast iron "Nicrosilal" (British Patent 378,508) was evolved and described in the *Journal* of the British Iron and Steel Institute, 1932, No. 2, p. 301. Both these irons were described in a paper by Norbury and Morgan to the American Foundrymen's Association, in the *Transactions* of that body, October, 1933, p. 267.

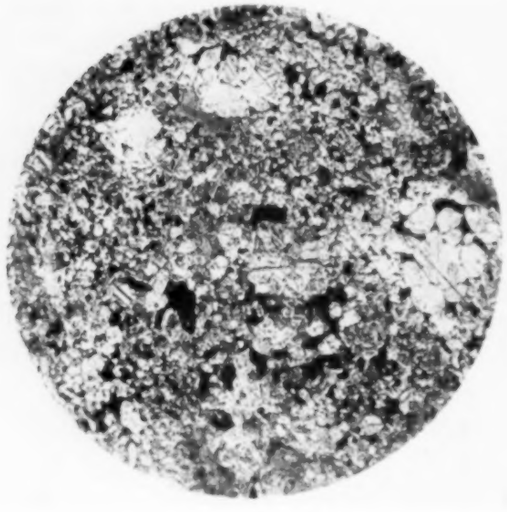
Several contributors to the discussion on Thyssen's paper drew attention to this earlier work and to the inadequate reference to it. Both of the heat resisting cast irons "Silal" and "Nicrosilal" are now manufactured commercially in this and various other countries.

J. G. Pearce

Metallurgy of Powdered Metals

SCHWEINFURT, *Germany* — This field of powdered metals is indeed so extensive that it is possible here to present only a brief outline of what is known in our country on this subject. The best idea of its extent can be obtained by glancing over the great number of related patents; even to mention the individual ones would require much space.

The hard carbide material known as "Widia" is known throughout the world. It was first developed by Franz Skaupy (now Dozent at the University of Berlin) in collaboration with Karl Schröter and Adolf Fehse at the Osram Gesellschaft, but now manufactured and marketed by Krupp. "Carboloy" is the corresponding material made in America; other hard carbides made



Metal Articles Pressed From Powdered Metal and Then Sintered Have a Spongy Texture. Analysis 7.5% graphite, 8% zinc, balance copper. 750 ×.

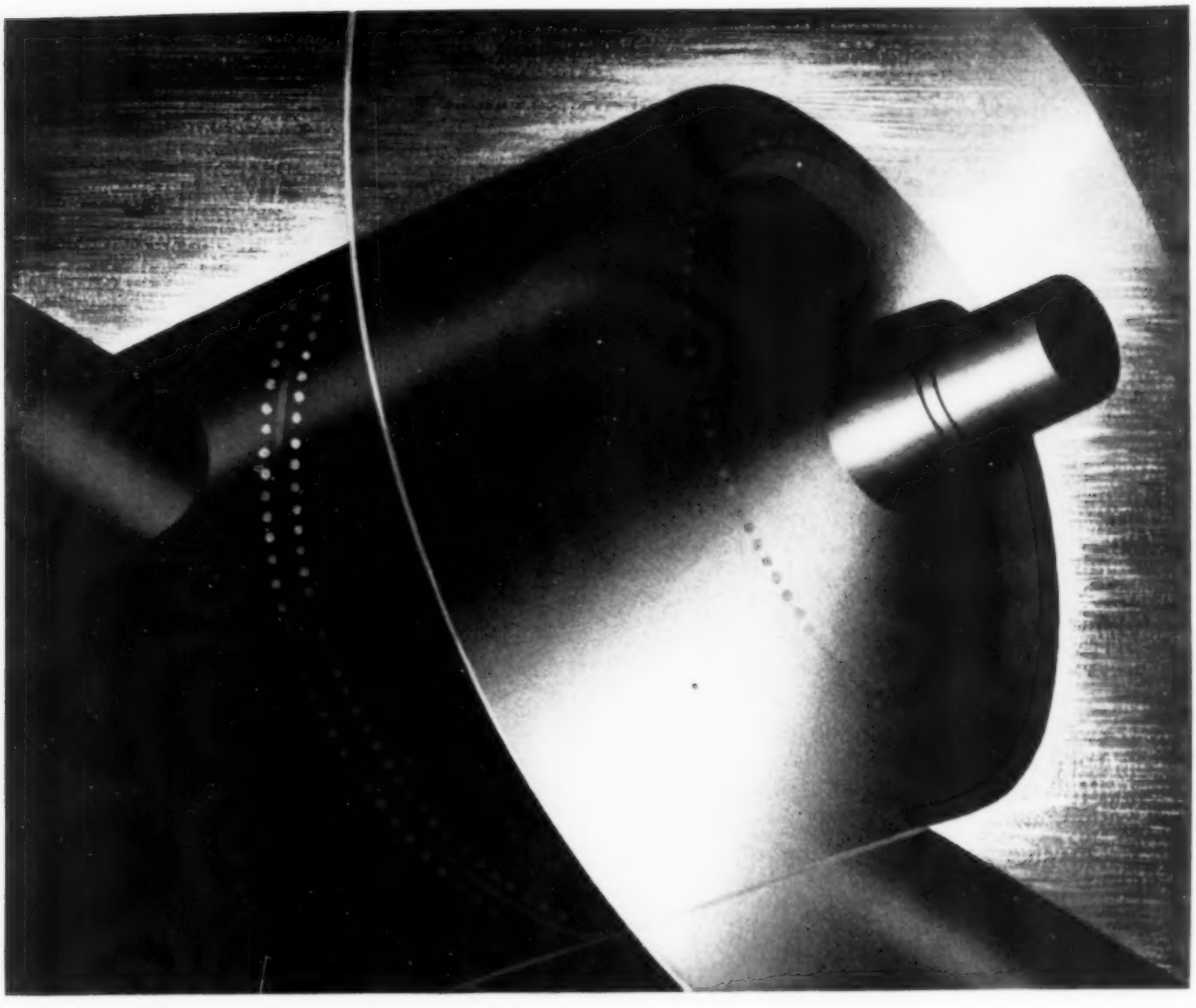
in slightly different ways have been given different trade names by their manufacturers.

The usual starting point for powder metallurgy (or *Metallkeramik*, as Dr. Skaupy calls it) is the existence of metal of high melting point (which, however, can be reached without too much difficulty in practical operation) that can be produced in finest particles, and then formed or pressed into the shape of a desired part; finally by sintering or fritting it can be bonded mechanically into a firm metallic body. Thus the way was led from the fabrication of filaments for electric light bulbs to hard metal cutting tools and to tungsten contacts, magnet cores and even to relatively soft bearing metals. From the refractory and difficultly worked metals tungsten, molybdenum, tantalum and osmium and their hard carbides, the process has been adapted to mixtures of copper, lead, graphite and zinc suitable for oil soaked bearings, to iron-nickel compositions valuable for magnetic properties, to composite welding wires and bi-metals, and porous plates for diaphragms, filters, catalyzers, and other chemical equipment.

Metal is powdered not only by chemical means, such as the reduction of oxides or by electrolysis, but also by physical means, such as in a mechanical pulverizer working on either solid or liquid metal, or by condensation from gaseous compounds such as carbonyls. While many such methods are patented, considerable secrecy surrounds the actual operating details. There are various methods of determining grain size; best known are *(a)* measurement under a microscope and *(b)* sedimentation analysis. Precise apparatus must be used to classify the material into the various grain sizes. This is very important for obtaining uniform parts, since with varying grain size neither volumetric measurement nor measurement by weight will put an accurate amount of powder into the forming die.

The pulverized metal (or mixture of pulverized metals) is pressed into shape either with or without a bonding medium. The desired part can then be secured by sintering in a correctly controlled atmosphere. This is the "ceramic"

Most Pressed Metal Parts Must Be Machined With Hard Carbide or Diamond Tools, Carefully Dressed and Sharp. Rough edges due to slightly dull drills



MOLY makes better surface-hardening steels

IT WOULD be difficult to find a better test of surface-hardened steels than in airplane engines. Cylinders, knuckle pins, propeller shafts, crankshafts and various gears are subjected to particularly severe service. . . Hence the large number of instances in which such parts are made of Molybdenum surface-hardened steels.

There are also many other applications, outside the airplane field, in which the outstanding quality of "Moly" surface-hardened steels to meet the hardest of service requirements has been demonstrated over and over. Whether the process is carburizing or nitriding, the results are the same — and are dependent on the Moly content.

The practical reasons are easily explained. . . Moly increases the speed of penetration and gives a deeper, harder case. The core physical properties are exceptionally good, and there is no susceptibility to temper embrittlement. Distortion on quenching is slight — and uniformly predictable.

Moly cuts costs . . . It reduces the processing time in surface-hardened steels; lowers the rejection percentage. Moly improves steel . . . It makes it stronger, tougher, more resistant to wear, creep, corrosion. Moly creates sales . . . It makes a more serviceable, longer-lasting, more satisfactory product.

A more detailed account of "industry's most modern and versatile alloy" is given in our interesting technical book, "Molybdenum," which is yours for the asking. And, "The Moly Matrix," published periodically, will keep you informed on the latest Moly developments. Shall we put you on the mailing list? Climax Molybdenum Company, 500 Fifth Ave., New York.

CUTS COSTS CLIMAX Mo-lyb-den-um CREATES SALES

method. Obviously the incipient welding of metallic particles, each to each, must not be prevented by oxide or dirt. The processes carried through are described in the patent literature; there are certain limitations as to relation of cross-section to depth, draft or taper in cylindrical dies, location of flanges or bosses, pressure developed by press, strength of die steels, clearances around plunger and so on.

An important point is that powder metallurgy has developed new alloying possibilities. Elements that are insoluble in each other in both the solid and liquid state, and furthermore widely separated by their specific gravities, can be suitably mixed and combined to form "alloys" with special properties. Another unique characteristic is the porosity of the part in production, which can be secured in any desired degree depending on the pressing operation, and the presence or absence of an addition agent which is vaporized during heat treatment. A further exposition of this point is contained in Dr. Skaupy's small book "Metallkeramik" published by Verlag Chemie, G.m.b.H., Berlin (1930, with 1935 supplement).

At this point should be mentioned certain materials — for example, bearing metals — which must be finished by cutting tools. (Despite an unusual fineness of pressed surfaces coming from accurate and highly polished dies, the sintering causes some volume change.) These materials differ in character from melted alloys in that they are surprisingly hard to machine. In turning, good results are obtained by the use of high cutting speeds, i.e. over 250 ft. per min., and by the use of hard carbide tools or diamonds. However, even the hard carbides must have special properties in order to retain good tool life; frequent regrinding is necessary.

Drilling or boring is also difficult because of the brittleness and somewhat low mechanical strength. Ugly edges, as shown in the accompanying illustration, are often obtained when the tool is not sharp enough and causes the edges to crumble slightly. The alloy illustrated contains 1.5% graphite, 8% zinc, and the balance copper — obviously one that could not be made by ordinary foundry methods.

In view of the unusual properties of these new materials, however, these drawbacks must be accepted as characteristic.

Other details on the subject are contained in the interesting article by Charles Hardy, published in METAL PROGRESS for July, 1933.

HANS DIERGARTEN

PERSONALITIES

C. H. Herty, Jr., at a meeting of the Philadelphia Technical Society on Dec. 7, was the first recipient of the Francis J. Clamer Medal for most meritorious invention, discovery, or research work in metallurgy.

Coolidge A. Karns, formerly metallurgist at Republic Steel Corp. Buffalo plant, has been granted the two-year fellowship established by the Molybdenum Corp. of America in the Metals Research Laboratory of Carnegie Institute of Technology.

Otto L. Lehecka has been made manager of the Tool Steel Dept. of Hamilton Steel Co., Cleveland.

Henry D. Nickol is working as graduate assistant in metallurgical research at Penn State College.

Maxwell M. Kessler has left the A. M. Byers Co. to take a position as metallurgist at the Ohio Works of the Carnegie-Illinois Steel Co.

Weldon S. Wertz has accepted a position in the Development & Research Dept. of Bethlehem Steel Co.

H. Ernest Munch is now with the Tractor Works of the J. I. Case Co. at Racine, Wis.

On Nov. 1 **David J. Giles** was promoted from chief metallurgist to works manager of Latrobe Electric Steel Co.

The Robert W. Hunt Award, given by the American Institute of Mining and Metallurgical Engineers for the best technical paper of the year on iron and steel manufacture, has been conferred on **C. C. Henning**, assistant general metallurgist for Jones & Laughlin.

T. N. Armstrong, formerly of the Norfolk Navy Yard, has joined the International Nickel Co. in the Development and Research Department.

William H. C. Webster is metallurgist for New York Shipbuilding Corp. at Camden, N. J.

Thomas B. Davies, who was district sales manager in Buffalo, has been transferred to Republic Steel Corp.'s Alloy Steel Division in Massillon as special representative.

H. A. Schwartz of Cleveland was the author of a paper for the conference sponsored by the Belgian Foundry Association in Brussels in September.

Harvey B. Jordan has been appointed Cleveland district manager of American Steel & Wire Co.

Scott Mackay, formerly at University of Wisconsin, has been made professor of ferrous metallurgy, Rensselaer Polytechnic Institute, Troy, N. Y.

John L. Christie, Bridgeport Brass Co., has been nominated director of the American Institute of Mining and Metallurgical Engineers.

The Perkin Medal of the Society of Chemical Industry will be presented to Prof. **Warren K. Lewis** of Massachusetts Institute of Technology on Jan. 10.